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This report was prepared by the Environmental Protection Agency (EPA) in response to a request from the governor of Florida to provide recommendation on indoor radiation exposure due to radium-226 in Florida phosphate lands (44 FR 38664). The report evaluates radiation levels in existing structures,the health impact of this radiation exposure, the cost-effectiveness of controls, the social and economic impact of potential radiation controls, and the alternatives available for radiation protection to minimize adverse risk to the public. The report concludes that the major exposure problem is associated with build-up of radon in residences constructed on land containing radium-bearing materials related to phosphate ores. The principal radiation health threat is an increased risk of lung cancer, which is dependent both on the indoor concentration of radon decay products and the period of exposure. The analysis projects that over a normal lifetime, persons residing in homes on phosphate lands in the study area experience and average lung cancer risk 35 percent greater than normal, and that those residing in homes exhibiting the highest levels measured experience a risk of lung cancer 2-4 times the U.S. average.

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INDOOR RADIATION EXPOSURE
DUE TO RADIUM-226 IN
FLORIDA PHOSPHATE LANDS

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PREFACE

The Office of Radiation Programs of the Environmental Protection Agency endeavors to protect public health and preserve the environment by carrying out investigative and control programs which encompass various sources of radiation. Pursuant to this goal, the Office's Criteria and Standards Division and Eastern Environmental Radiation Facility initiated a study in June 1975 to examine the radiation impact of living in structures built on phosphate lands. This study was carried out in conjunction with the Florida Department of Health and Rehabilitative Services and the Polk County Health Department. The purpose of this report is to present the findings of that study; these include estimates of the radiation levels, evaluations of the cost-effectiveness of controls, and possible actions that can be taken to reduce such levels. Readers of this report are encouraged to inform the Office of Radiation Programs of any omissions or errors. Comments or requests for further information are also invited.

We wish to express our gratitude to the staffs of the Florida Department of Rehabilitative Services and the Polk County Health Department for their cooperation and assistance. Staffs of the Eastern Environmental Radiation Facility in Montgomery, Alabama, and the Environmental Monitoring and Support Laboratory in Las Vegas, Nevada, contributed substantial efforts in sample and data analysis. We also offer our thanks to officials of the phosphate industry for their help.

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SUMMARY OF FINDINGS

As a result of the presence of elevated concentrations of radium-226 and other radionuclides in phosphate ores and mining wastes, many individuals residing in Central Florida are exposed to undesirable levels of radiation. In the absence of adequate measures to protect public health, many more could be exposed in the future, depending upon developing mining and land use patterns. The major exposure problem is associated with structures, principally residences, that are constructed on, near, or using radium-bearing materials related to phosphate ores. In this study, annual average indoor radon decay product concentrations in excess of 0.03 working level (WL) were measured in approximately 15 percent of the structures surveyed. Normal occupancy at this level of exposure would result in an annual cumulative exposure of 0.6 working level months (WLM).* Lifetime residence in a structure exhibiting this level could result in a doubling of the normal three to four percent risk of fatalities due to lung cancer. At present there are no adequate guidelines to protect the public from this and most other similar sources.

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*Working level month means exposure to one working level (WL) for 170 hours (a working month). Exposure of non-miners (75% occupancy) in residential environments to radon daughters at one working level for one year is approximately equivalent to 27 WLM. A working level is defined as any combination of short-lived radon daughter products in one liter of air that can result in the ultimate emission of 1.3 x 10^5 Mev of alpha energy. Normal occupancy is assumed to be 75 percent residence in this report.

Areas affected by the radium-bearing phosphate materials also generally exhibit elevated gamma radiation exposure levels. However, the health risk accompanying exposure to radon decay products in a structure is generally much greater than that for the associated gamma exposure. Therefore, assuring protection from elevated air concentrations of radon decay products is of primary concern, with protection from gamma exposure of only secondary importance.

Evaluation of the cost-effectiveness[*] of various measures for controlling airborne radon decay products in new (i.e., planned) and existing structures suggests that several appear economically reasonable. The application of control measures in a residence was found to be warranted on this basis when initial levels are greater than 0.005 WL above normal. Although most of the control measures evaluated have been tested and used in other situations, none have been thoroughly tested in Florida.

The cost of controlling gamma radiation in existing structures is high because remediation would require extensive modifications to the foundation and to the soil under and around it. It was concluded that the application of control measures to reduce gamma radiation exposure is not cost-effective in existing structures. However, in planning residences, the design and siting of the structure can be arranged to provide additional gamma shielding for little cost. In most new residences, it appears to be cost-effective to limit external gamma radiation exposure rates to 5 μR/h above normal (11 μR/h gross), or less.

---

[*] Meaning the degree to which the economic cost of an action (in this case, the use of control measures) is justified by the positive result of the action (e.g., health risk reduction).

Land and wastes associated with other types of ores throughout Florida, as well as other parts of the United States, may pose similar health risks due to the presence of radium and other radionuclides in above normal concentrations. While these findings apply to a specific situation in Central Florida, Federal, State, or local authorities with similar problems in other areas may find them useful. Local factors, including cost and other practical considerations, may have to be weighed in applying these results to situations other than phosphate-related land in Florida.

During the course of this study, the Agency also acquired information about other types of land from the phosphate industry, universities, and state and local agencies, as well as from its own measurements. Sizeable areas of land in Florida containing monazite sand deposits or wastes from the processing of various minerals may also present health risks similar to those posed by phosphate lands and wastes. Some of these lands may also pose health risks due to radiation associated with radionuclides resulting from the decay of thorium-232. A study carried out by the State of Florida to characterize the health impact in these areas would appear to be indicated, as a basis for any control action that may be necessary.

SECTION 1.0

INTRODUCTION

Naturally-occurring radionuclides such as uranium, thorium, and their decay products, as well as tritium, carbon-14, and potassium-40, are found throughout the environment and are usually fairly evenly distributed. However, some geological strata, such as marine phosphorite deposits, contain significantly elevated concentrations of uranium, thorium, and their decay products. In the United States, the phosphate deposits of Florida contain concentrations of uranium and its decay products at levels about 30-60 times greater than those found in average soil and rock. The presence of this radioactive material in extensive land areas in Central and Northern Florida creates the potential for radiation exposure of the general population living on or near this land.

In June 1975, the U.S. Environmental Protection Agency (EPA), in conjunction with the Florida Department of Health and Rehabilitative Services and the Polk County Health Department, initiated a pilot study to examine the radiological impact of living in structures built on reclaimed phosphate land. The study was a part of a comprehensive investigation conducted by EPA of the overall impacts of releases of radiation and radioactive materials directly or indirectly from the phosphate industry.

In September 1975, the Administrator of the Environmental Protection Agency informed the Governor of Florida that the Agency had found elevated radon decay product levels in buildings constructed on land reclaimed from old phosphate mining areas (Tr 75). He noted that the primary health concern is increased risk of lung cancer to the occupants. The Administrator recommended that "as a prudent interim measure the start of construction of new buildings on land reclaimed from phosphate mining areas be discouraged."

As a result of the Agency's preliminary findings, discussions were held with appropriate Federal, State, and local agencies, as well as industry representatives to determine the appropriate course of action. The following actions were determined to be of principal importance:

1. Complete an assessment of the health risk in the study structures over a longer period of time.

2. Perform an evaluation of the number of structures affected and the magnitude of the impacted land within the State of Florida.

3. Develop guidelines for use by the responsible agencies and the public in determining acceptable indoor radiation levels.

4. Develop guidelines for use by the responsible agencies and the public in evaluating existing structures for possible remedial action.

5. Develop criteria for evaluating the indoor radiation exposure potential of undeveloped land.

6. Determine if new reclamation techniques are needed and feasible.

The activities of the Environmental Protection Agency since then have been focussed on actions one, three, four, and five, with the State and local health agencies focussing on actions two and four. Industry efforts have been focussed on action six. However, in order to evaluate the problem expeditiously, there has been an exchange of data and information on each of these items among all groups involved.

The purpose of this report is to present data gathered in the EPA study, estimate the radiation levels in existing structures, evaluate the cost-effectiveness of controls, evaluate the social and economic impact of potential radiation protection controls, and delineate the alternatives available for radiation protection to minimize adverse risk to the public. A separate report will address item five, i.e., the development of criteria for the evaluation of undeveloped land to determine its suitability for residential development.

SECTION 2.0

PROBLEM DESCRIPTION

2.1 INDUSTRY OVERVIEW

In 1975 about 83 percent of U.S. phosphate mine rock production occurred in Florida, primarily in the Central Florida Land-Pebble district with the remainder in Tennessee and several western states (St 77). Figure 1 illustrates the primary Florida phosphate deposit areas. About 174 million tons of phosphate mine rock was extracted in 1975 through the strip mining of approximately 5,000 acres of land. Over the 80 years that phosphate has been mined in Florida, a total of about 2 billion tons of phosphate mine rock has been extracted from about 120,000 acres of land (St 77, Wa 74).

2.2 MINING TECHNIQUES & PRACTICES

The standard mining practice in the Florida land-pebble phosphate fields is to strip the overburden and mine the phosphate matrix with draglines. Electric-powered walking draglines with 35 to 70 cubic yard buckets work in cuts varying from 150 to 250 feet in width and from a few hundred yards to a mile or more in length. The cuts are from 50 to 70 feet deep. Overburden is stacked on unmined ground adjacent to the initial cut by means of a dragline, until successive cuts allow it to be cast into adjacent mined-out cuts. As each cut is stripped of overburden

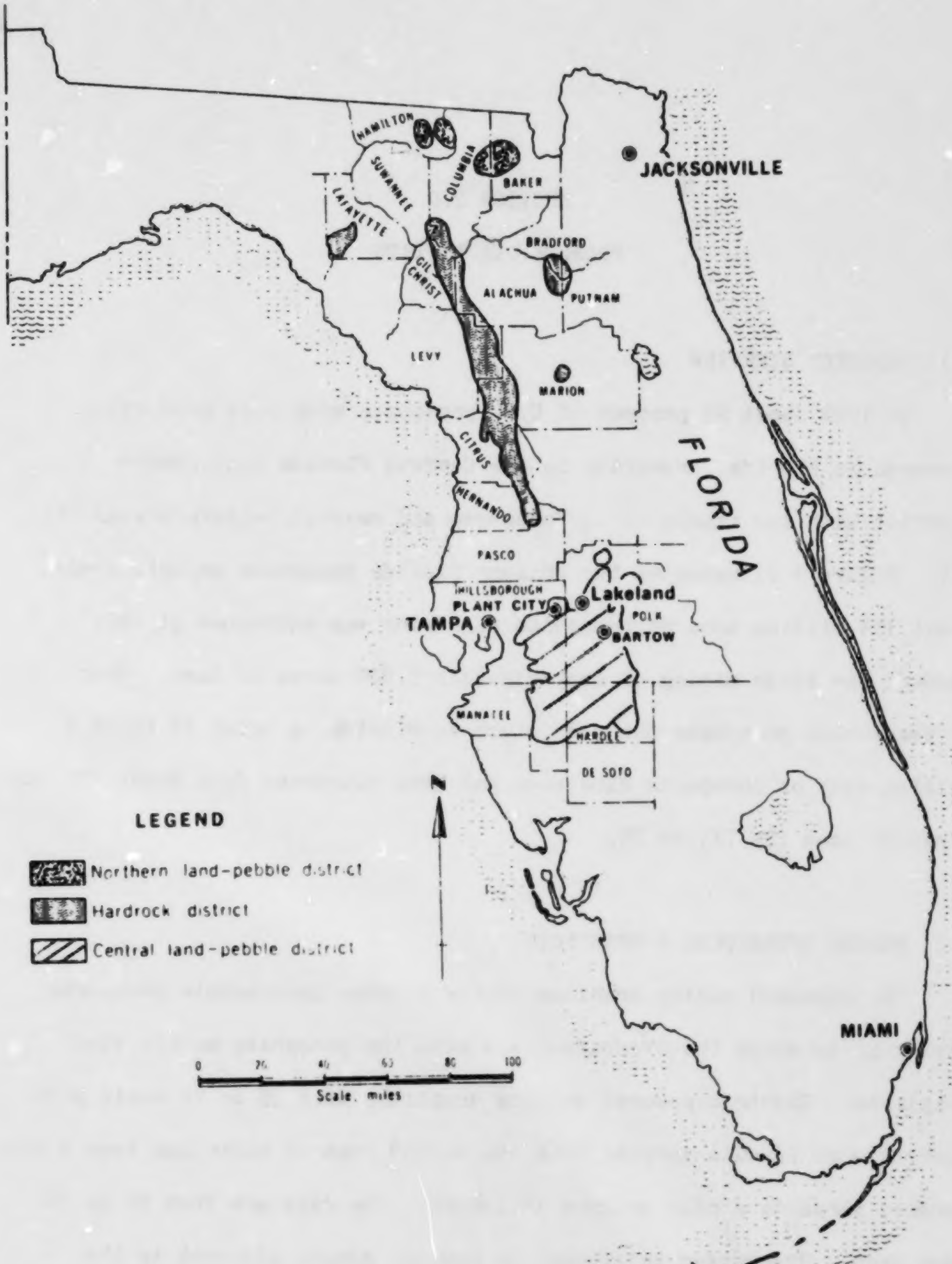

JACKSONVILLE
HAMILTON
SUWANNEE
COLUMBIA
BAKER
LAFAYETTE
BRADFORD
GIL CHRIST
ALACHUA
PUTNAM
LEVY
MARION
FLORIDA
CITRUS
HERNANDO
PASCO
HILLSBOROUGH
PLANT CITY
Lakeland
POLK
TAMPA
BARTOW
MANATEE
HARDEE
DE SOTO
N
LEGEND
Northern land-pebble district
Hardrock district
Central land-pebble district
MIAMI
0
20
40
60
80
100
Scale, miles

Figure 1. Phosphate deposits in Florida. (WA 74)

and then mined, the ore is stacked in a suction well or sluice pit that has been prepared on unmined ground. High pressure water is used to produce a slurry of about 40 percent solids from the matrix. This slurry is then pumped via pipe to the washer plant. In this manner, a typical operation will mine about 400 acres of land, remove 13 million cubic yards of overburden, and mine 9 million yards of matrix per year.

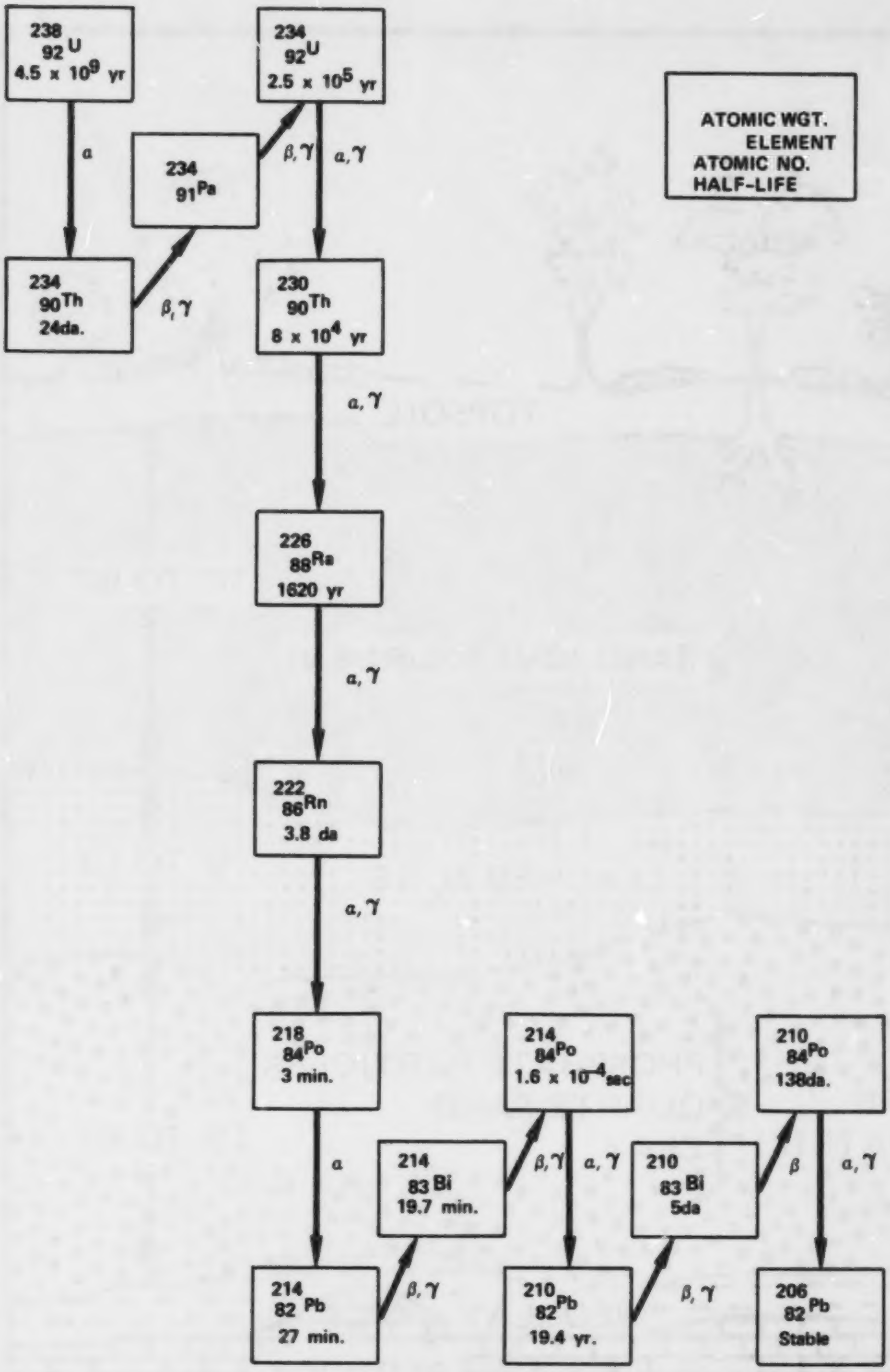
Water is used in the phosphate beneficiation or ore refinement process, in addition to being used as a transportation medium. Both fresh water from deep wells and reclaimed water from slime settling ponds are used by the phosphate industry, at a rate of approximately 10,000 gallons to produce one ton of marketable phosphate rock. As the mining progresses, mined-out areas are used for the disposal of tailings and slimes, in addition to overburden. Approximately one ton of slimes and one ton of sand tailings must be disposed of for each ton of marketable phosphate rock produced. Some of the sand tailings and overburden are used to construct retaining dams in mined-out areas, behind which phosphatic clay slimes settle and dewater.

Beneficiation methods differ slightly, depending on screen analysis of the feed, the ratio of washer rock to flotation feed, the proportions of phosphate, sand, and clay in the matrix, and equipment preferences. Through a series of screens, in closed circuit with hammer mills and log washers, the matrix is broken down to permit separation of the sand and clay from the phosphate-bearing pebbles. Three concentrations of marketable phosphate rock are produced: a 3/4-inch by 14-mesh pebble, a coarse 14 by 35-mesh fraction, and a fine 35 by 150-mesh fraction. The washed, oversized pebble fraction is a final product. The 14 by 35-mesh fraction is called the coarse feed, from which a coarse concentrate is obtained by gravity and flotation processes. The tailings or waste from this fraction are used in dam construction or land reclamation. The 35 by 150-mesh fraction is processed through a flotation section to recover a fine concentrate. The waste, a clay slime, is impounded in areas that have been mined.

2.3 PRESENCE OF RADIOACTIVE MATERIALS

Uranium is present in the phosphate matrix in concentrations which generally average about 100-150 ppm (or about 35-55 picocuries natural uranium per gram of matrix). The uranium is usually in equilibrium with its radioactive decay products, at least through radium-226 (Gu 75). This means that for each curie (a measure of radioactivity equal to 3.7×10^{10} disintegrations per second) of the parent radionuclide, one curie of each daughter radionuclide is also present. The uranium-238 decay scheme is shown in Figure 2.

Radioactivity is also present in parts of the overburden. Figure 3 illustrates the general geological structure found throughout much of the Florida land pebble district. A "leach zone," which averages five feet thick and covers much of the pebble deposits, contains uranium in concentrations comparable to that of the matrix. In some areas other portions of the overburden also contain elevated radioactivity, although



238 92 U 4.5 x 10^9 yr
a
234 91 Pa
β, γ
234 90 Th 24da.
β, γ
234 92 U 2.5 x 10^5 yr
a, γ
230 90 Th 8 x 10^4 yr
a, γ
226 88 Ra 1620 yr
a, γ
222 86 Rn 3.8 da
a, γ
218 84 Po 3 min.
a
214 82 Pb 27 min.
β, γ
214 83 Bi 19.7 min.
β, γ
214 84 Po 1.6 x 10^-4 sec
a, γ
210 82 Pb 19.4 yr.
β, γ
210 83 Bi 5da
β
210 84 Po 138da.
a, γ
206 82 Pb Stable
ATOMIC WGT.
ELEMENT
ATOMIC NO.
HALF-LIFE

Figure 2. Uranium-238 Decay Series

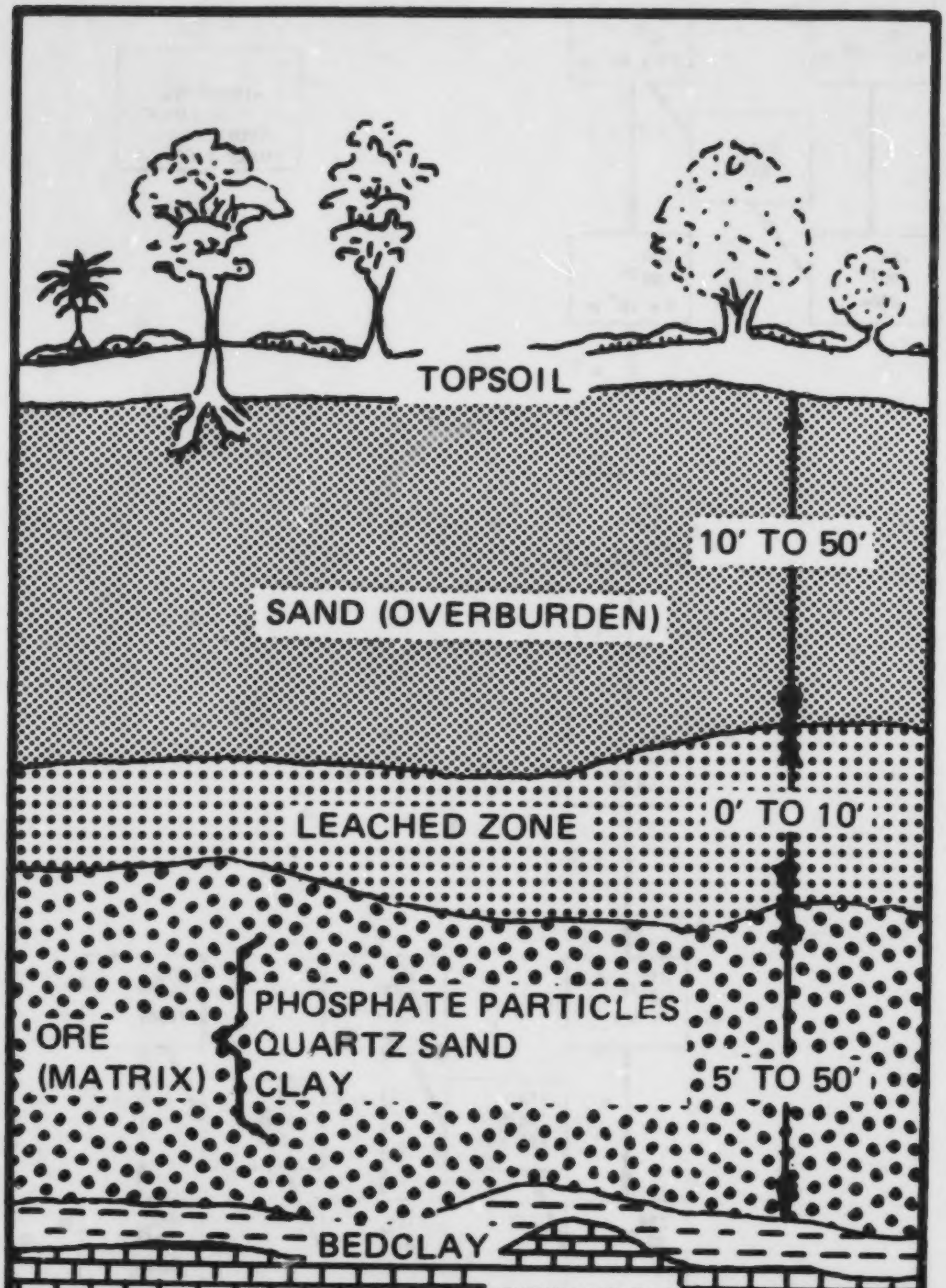

TOPSOIL
10' TO 50'
SAND (OVERBURDEN)
LEACHED ZONE
0' TO 10'
ORE
(MATRIX)
PHOSPHATE PARTICLES
QUARTZ SAND
CLAY
5' TO 50'
BEDCLAY
BEDROCK

Figure 3. Typical Profile in Study Area (Fo 72)

not in as high concentrations (Ca 66). The radioactivity is generally associated with the phosphate, itself, since the uranium replaces the normal calcium in apatite. Consequently, the marketable ore and slimes containing most of the phosphate also contain most of the associated radium. Two-thirds of the phosphate originally contained in the matrix remains in the marketable rock, with the remainder primarily in the slimes.

Soil throughout the United States typically contains between 0.2 and 3 pCi radium-226 per gram. One would anticipate that normal Florida soils would contain this concentration range of radium-226 in areas that have been undisturbed by mining. However, anomalies may occur in areas where surface waters have exposed phosphate deposits or where such deposits are very close to the surface. Measurements indicate that the latter situation occurs in several areas in Central Florida.

2.4 ORIGIN AND TRANSPORT OF RADON-222

Unmined, reclaimed and disturbed phosphate land can be composed of widely varying concentrations of radium-226, as a function of the relative thickness and presence of low activity overburden soil and sand tailings as compared to higher activity matrix, slimes, or leach zone material. The presence of radium-226 and its decay products in soil presents a potential source of gamma exposure to individuals living or working above the soil. However, of much greater concern is exposure arising from the release of radon-222, a noble gas decay product of radium-226 with a 3.85-day half-life. It may diffuse through the soil into the atmosphere, where observed radon-222 concentrations in the air are highly variable due to the influence of factors such as precipitation, barometric pressure, and atmospheric thermal stability.

Radon-222 that diffuses up through soil also readily passes through most concrete slabs and other construction materials. Within a structure, the principal route of removal of radon is by ventilation or leakage through the structure's walls, window frames, etc. Radioactive decay of the material as a removal process is generally small compared to ventilation and leakage. Radon-222 is probably not in equilibrium with its decay products in most situations within structures, due to the effects of ventilation and plate-out of decay products as particulates on inside surfaces.* The level of radon-222 and its decay products is thus dependent upon the rate at which radon diffuses into the structure and the rate at which it is removed by ventilation, leakage, and decay. Clearly, if ventilation is low, radon and its decay products have the potential to build up significantly within a structure. Figure 4 depicts the movement of radon and daughters into and out of a structure.

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*The degree to which plate-out is a contributing factor is highly variable, depending primarily upon exposed surface area and the free ion fraction; the effect of plate-out, however, is of relatively small significance in comparison with that due to ventilation.

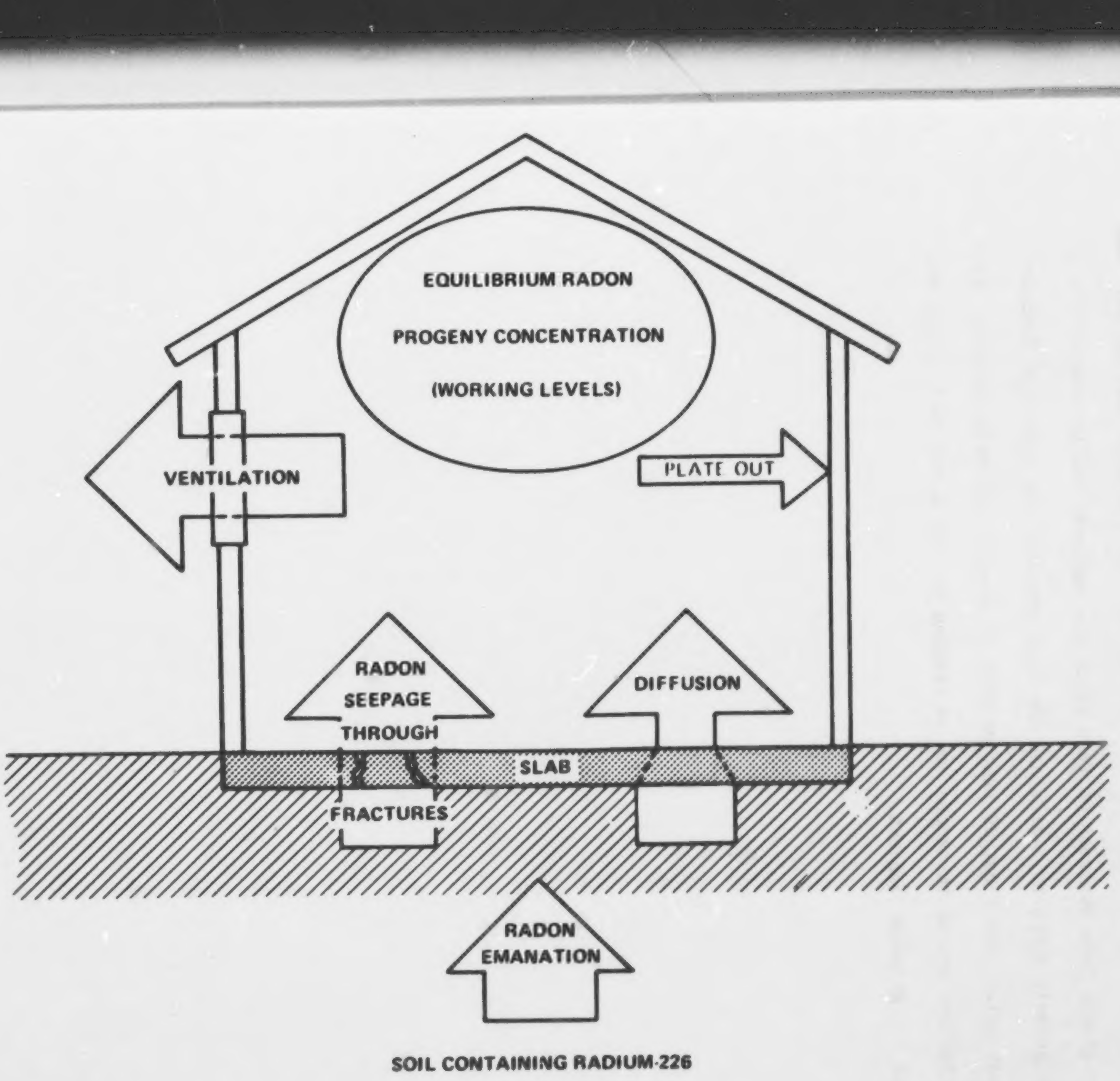
EQUILIBRIUM RADON
PROGENY CONCENTRATION
(WORKING LEVELS)
VENTILATION
PLATE OUT
RADON
SEEPAGE
THROUGH
DIFFUSION
SLAB
FRACTURES
RADON
EMANATION
SOIL CONTAINING RADIUM-226

FIGURE 4.
FACTORS INFLUENCING RADON DECAY PRODUCT CONCENTRATIONS IN STRUCTURES

Radon-222 which enters the atmosphere via transport through soil can originate from hundreds of feet below the surface, but because of its relatively short half-life and the time required for diffusion through most soils, the first 20 feet of soil is usually the major source. This effective source thickness can be reduced to just a few feet if the soil has a high water content.

SECTION 3.0

OBSERVED RADIATION LEVELS

3.1 NORMAL BACKGROUND LEVELS

3.1.1 General Perspective

Exposure to background radiation results principally from cosmic radiation sources and normal concentrations of radioactive elements originating in the atmosphere of the earth's crust. Both of these components vary throughout the United States, depending upon altitude, latitude, and the makeup of the terrestrial environment. However, in some areas the presence of elevated soil radioactivity due to either natural phenomena or to human alteration of the environment can lead to radiation exposure significantly in excess of normal background exposure. The purpose of this section is (1) to place the radiation levels observed in Central Florida structures built on phosphate land in perspective with radiation exposure levels generally expected in Central Florida and in other parts of the country, and (2) to provide a framework for decision-making regarding measurement of radiation levels and implementation of radiation protection recommendations in situations where the exposures are elevated.

3.1.2 Cosmic Ray Exposure

Whole body dose rates at sea level in the United States from Florida to Alaska range from about 30 to 45 mrem/year (3.4 to 5.1 μrem/h), respectively. At 45 N latitude, the variation with altitude from sea level to 8,000 ft. is about 40 to 200 mrem/year (4.6 to 22.8 μrem/h), respectively (Kl 72). In general, the estimated annual cosmic-ray whole-body doses in the U.S. range between 30 mrem for Hawaii to 130 mrem for Wyoming. For Florida it is estimated to be 35 mrem.

In order to verify this estimate for Florida, measurements were at the center of two reasonably large Central Florida lakes with a pressurized ion chamber. The measured cosmic-ray contribution, excluding the neutron component, was 35 mrem/y (4.0 μrem/h) at Lake Pierce and 31 mrem/y (3.5 μrem/h) at Lake Hamilton for an average of about 33 mrem/y (3.8 μrem/h). The measured values at the two lakes agree quite favorably with those previously reported. The neutron component could add an additional 6 mrem/y (0.6 μrem/h), but this will be ignored because external radiation measurements made in Central Florida as cited in this document do not record neutron dose (Lo 66).

3.1.3 Terrestrial External Gamma Ray Exposure

Naturally radioactive isotopes are constituents of a number of minerals present in the terrestrial environment. Naturally-occurring radionuclides contribute to both external and internal irradiation. The significant external gamma exposures are produced by potassium-40 and the decay products of the uranium and thorium series.

Based upon numerous reported measurements, estimates have been made of the range and mean of whole-body doses due to terrestrial radiation by population and by area for the United States. Ninety percent of all areas fall in the range of 15 to 130 mrem/year (1.7 to 14.8 μrem/h), while ninety percent of the population falls in the range of 30 to 95 mrem/year (3.4 to 10.8 μrem/h). The estimated national mean is 55 mrem/year (6.3 μrem/h).

3.1.4 Total Background External Radiation Levels

Total average background radiation levels in the various States have been estimated to range between 70 mrem/year (8 μrem/h) and 225 mrem/year (26 μrem/h) with an overall U.S. average of about 85 mrem/year (10 μrem/h). The average of 879 measurements of natural background levels by Levin, et al., in Florida was 59 mrem/year (6.7 μrem/h) (Oa72).

Measurements of the total normal background in Central Florida were made by EPA in several locations with various types of detection equipment. The average outdoor gamma exposure levels measured with portable scintillation instruments at 26 structures built on unmined non-mineralized land was 45 mrem/year (5 μrem/h). For these same structures, indoor gamma exposure levels averaged 43 mrem/year (4.9 μrem/h). TLD's were placed in Dundee, Lake Wales, and Polk City, Florida, which are outside the phosphate area, and left for an extended time period. The average of these measurements was 41 mrem/year (4.7 μrem/h). Pressurized ion chamber measurements were made at nine locations outside the phosphate region. The average of these measurements was 51 mrem/year (5.8 μrem/h). It should be noted that the measurements by portable scintillation instruments and TLD's will not reflect cosmic ray exposure as accurately as the pressurized ion chamber. Considering this, these field data show adequate intercomparison as well as agreement with the values listed in the literature. They suggest that the normal external gamma exposure in Central Florida is about 60 percent of the average for the United States.

3.1.5 Radon-222 and Decay Product Exposure

Natural radionuclides are also present in the air. The greatest dose to people from airborne natural radioactivity generally arises from the decay products of Rn-222. Measurements of radon-222 concentration in air in the U.S. suggest that it is normally present in concentrations ranging from 40-1000 pCi/m^3 (0.04 - 1 pCi/l) (Na75). Radon in the atmosphere primarily originates from the decay of radium in soils and rocks. The outdoor radon concentration at ground level depends on the rate of radon emanation from the soil and how rapidly it is dispersed.

Inside structures the concentration of radon-222 and its decay products is generally considerably higher than corresponding outdoor concentrations because of poorer indoor dispersion characteristics. Although the number of measurements made over extended time periods throughout the United States is quite limited, the data suggest that the normal range of radon decay product levels is from about 0.0001 to 0.005 working level (WL), with an average of about 0.002 WL. Although levels greater than 0.005 WL can be found, these are frequently due to combinations of larger than normal radium-226 concentrations in soil and building materials, coupled with poor ventilation. Measurements by EPA using the TLD air pump system in Central Florida in 26 structures on non-mineralized land showed an average of about 0.004 WL (.0007-.014 WL). Data obtained by the University of Florida and the State Department of Health and Rehabilitive Services for this parameter on non-phosphate land are 0.002 and 0.004 WL, respectively (De 78, Ro 78). Review of these data indicates that the range is within that expected by studies of other investigators throughout the United States. Further, the three data sets compare quite favorably, although the University of Florida data is for a smaller sample of residences measured using only a few grab samples.

3.1.6 Other Anomalous Radiation Areas in Florida

In addition to the phosphate lands in Florida there are other regions in the State where elevated radiation levels have been noted, because of the presence of ores containing trace quantities of uranium, thorium, and their decay products. These areas are primarily along the coast between Punta Gorda and Venice, and along the northeastern coastal region. Deposits of monazite sands are the primary source of radioactive materials. In these areas, radiation levels are as high as or higher than those observed in the phosphate region. Little detailed information is available regarding these areas because they have not been investigated to any meaningful extent. Limited measurements by EPA around Punta Gorda and Venice identified external gamma radiation exposure levels up to 30 μR/h (260 mrem/y). However, the size of the impacted areas appears to be small. In the northeastern area of Florida, gamma radiation exposure levels in excess of 100 μR/h (880 mrem/y) have been reported by the State of Florida Department of Health and Rehabilitative Services. They also suggested that the impacted area in this region could be quite large. No information exists on radon-222 and radon-220 concentrations in these areas.

3.1.7 Background Summary

Based upon EPA's measurements and review of previously reported data, it is concluded that the normal background radiation level in and around a Central Florida structure located away from phosphate-related land can be characterized by the following parameters:

External gamma exposure rate - 6 μrem/h

Indoor radon decay product level - 0.004 WL

Although these values are somewhat variable, as indicated by the data, they provide a representative basis for most decisions concerning the need for remedial action for radiation protection.

3.2 SUMMARY OF RADIATION MEASUREMENTS AND EVALUATIONS

3.2.1 Evaluation of Radon Progeny Levels in Structures

Radon progeny levels were evaluated at 133 locations in Polk County with Radon Integrating Progeny Sampling Units (RIPSU). This device draws air through a particulate filter, and measures radiation from radon progeny with a thermoluminescent dosimeter (TLD). These air sampling units were rotated to the various locations on a periodic basis to insure several measurements at each structure, and to reflect any seasonal or diurnal variations in radon decay product concentrations. For the purpose of evaluation, the 133 locations were categorized according to structure type (slab, basement, crawl space, or trailer construction) and land category (reclaimed, mineralized, or non-mineralized). Of the total sample, 22 structures were from the original pilot study initiated by EPA and the remainder were selected later as a part of the group chosen by the Florida Department of Health and Rehabilitative Services (DHRS). The distribution of indoor working level measurements in the two samples differs, although this is expected due to the smaller pilot study sample size and the practical aspects of selecting the structures. In the selection of the EPA pilot group, houses known to be on reclaimed land were chosen on the basis of elevated external gamma measurements made on-site. The DHRS study group, however, was selected solely by review of land records to identify reclaimed land. It is understandable, therefore, that a greater percentage of structures in that group exhibit lower external gamma and indoor radon decay product levels than in the EPA pilot group. The distributions of radon decay products in each group are shown in Table 1.

TABLE 1
EPA and DHRS Indoor Radon Decay Product Level
Distribution by Number of Structures (Percentage in parenthesis)

Level (WL gross)	EPA	DHRS	Composite
	N=22	N=111	N=133
Greater than 0.05	5 (23%)	3 (2%)	8 (6%)
0.03 to 0.05	3 (14%)	9 (9%)	12 (9%)
0.01 to 0.03	4 (18%)	22 (20%)	26 (20%)
Less than 0.01	10 (45%)	77 (69%)	87 (65%)

From information collected in the survey, the land on which the structures were constructed was classified according to four categories: non-mineralized (no deposits), mineralized (deposits present, but unmined), reclaimed, and other (i.e., missing or incomplete information). Of the 133 structures, the gross average working level for each category is 0.003 WL (non-mineralized), 0.015 WL (mineralized), 0.016 WL (reclaimed), and 0.018 WL (other). This distribution, provided in more detail in Table 2, indicates that mineralized land has as much radiological impact as reclaimed land.

TABLE 2

Distribution of Indoor Radon Decay Product
Levels by Land Category

Land Use	N	WL<0.01	0.01 ≤WL <0.03	0.03 ≤WL<0.05	WL≥0.05
Reclaimed	93	59%	20%	13%	8%
Mineralized	9	44%	44%	12%	0
Non-mineralized	29	97%	3%	0	0
Unknown	2	0	100%	0	0

In order to determine the influence of structure design (particularly foundation design) on radon diffusion, the average working level measured in various types of structures was evaluated for four typical structure types found in central Florida: basement, slab-on-grade, crawl space, and trailers. The average value for each category (with the number of structures in parenthesis) is 0.020 WL (4), 0.015 WL (102), 0.01 WL (13), and 0.008 WL (14), respectively. Although sample size for some of these categories decreases the statistical significance of this distribution, this data suggests that crawl space and trailer designs result in less radon diffusion into a structure than typical basement or slab-on-grade construction.

The evaluations of indoor radon decay product levels by both land category and structure type can be combined to analyze the distribution of measurements as a function of these two parameters. For reclaimed land, the four types of structures were evaluated on the basis of percent working level distribution. For slab and crawl space construction the distributions are shown in Table 3.

TABLE 3

Distribution of Indoor Radon Decay Product Levels in Slab and Crawl space Structures on Reclaimed and Mineralized Land (RPISU)

Level (gross WL)	Slab	Crawlspace (including trailers)
	N=77	N=22
Greater than 0.05	9%	0%
0.03 to 0.05	12%	9%
0.01 to 0.03	23%	9%
Less than 0.01	56%	82%

Ventilation has been identified as a key factor in the buildup of indoor air concentrations of radon decay products. The use of air conditioning in the study structures was of interest because it was initially believed that maintaining a lower indoor temperature at a reasonable cost would entail reducing the degree of air infiltration from the outside air. However, studies by EPA show that operation of a central air conditioning system tends to reduce the indoor radon decay product levels when compared to no air flow (Wi 78). This is attributable to the increased influx of outside air due to leakage surmised to be the result of pressure differences brought about by the operation of the ventilation system, as well as the deposition or "plate-out" of decay products in the ventilation system. For structures with and without air conditioning the average working levels are 0.012 and 0.016 WL, respectively. This implies that any significant short term effects caused by operation of the air conditioning system may be largely balanced over a year by factors such as decreased usage during the cooler months.

3.2.2 Evaluation of Gamma Exposure Levels

Gamma exposure rate measurements were made at 1102 sites by EPA and DHRS. The gamma surveys were performed with a standard portable scintillometer held one meter from the floor or ground level for indoor and outdoor measurements, respectively. Average indoor and outdoor gamma exposure rates were estimated from several measurements in and around each structure.

The distribution of exposure rates was examined for different land categories. This is summarized in Table 4 for the three primary categories: non-mineralized, mineralized and reclaimed.

TABLE 4
Outdoor External Gamma Exposure by Land Category (N=1074)*

Level (μR/h)	Reclaimed	Mineralized	Non-Mineralized
	N=672	N=102	N=300
greater than 20	7%	1%	0%
11-20	26%	4%	3%
less than 11	67%	95%	97%
average gamma exposure	11 μR/h	7 μR/h	6 μR/h

*28 sites have unknown classifications

The influence of structural design, especially the degree of foundation shielding, was evaluated for the four structure types considered in this study. The average ratio of indoor gamma levels to corresponding outdoor gamma levels was found to be fairly similar for all structure types (about 0.8-0.9, as shown in Figure D.8). However, when controlling for gamma background "noise" contribution (e.g., from reflected primary radiation and radiation from structural materials themselves, the differences due to shielding are more pronounced for foundation (slab and basement) versus non-foundation (crawl space and trailer) structures. For levels above 10 and 25 μR/h, for example, the average indoor to outdoor ratio for these respective structure categories is roughly 0.4 and 0.8 (see Tables D.9 and D.10) These observations are consistent with the degree of floor shielding present with slab and basement construction, which have several inches of concrete, and with crawl space and trailer construction, which have either wood or thin metal flooring. In addition, a distribution plot by structure type for reclaimed land (Figure D.10) shows that only crawl space and trailer structures have indoor levels in excess of 20 μR/h.

3.2.3 Evaluation of Track-etch Data

Track-etch film was used in 153 structures selected in the pilot study for the purpose of providing another estimation of radon progeny levels. The film was placed in a structure for at least a year, after which a representative portion of the "etches" were counted to determine alpha energy deposition. This was translated into an estimate of indoor radon decay product level through the use of appropriate calibration curves. The details of this method are discussed in Appendix B. Because of the errors involved in this technique, particularly at indoor radon decay product levels less than 0.02 WL, the amount of useful data obtained is limited. Table 5 shows the distribution of track-etch data according to land classification.

TABLE 5

Distribution of Indoor Radon Decay
Product Levels According to Land Classification (Track-etch)
(M= Mineralized, N=Non-Mineralized, R=Reclaimed, and U=Unknown)

Level (WL)	M 8	N 27	R 112	U 6
Greater than 0.05	38%	0%	23%	0%
0.03 to 0.05	0%	4%	12%	0%
0.01 to 0.03	50%	41%	37%	0%
Less than 0.01	12%	55%	28%	67%

SECTION 4.0

RADIATION HEALTH RISK ESTIMATES

4.1 THE RISK TO HEALTH DUE TO THE INHALATION OF RADON DAUGHTERS

4.1.1 The Epidemiological Data Base

The carcinogenic nature of inhaled radon and its daughter products became known through observation of fatal lung disease in some groups of underground miners. The malignant nature of their disease was recognized as early as 1879 and specifically identified as bronchiogenic cancer in 1913 (Lu71). The association between these cancers and the miners' exposure to radon was first made in 1924.

Although there has been some argument that occupational hazards other than radon may be important, extensive studies have excluded many suspected causes of excess lung cancer among underground miners such as pneumoconioses, water in the mines, heredity, fungal growths, as well as a number of metals in the ore, i.e., nickel, chromium, arsenic, and bismuth (Fr48, Hu66). Exhaust fumes from diesel engines are often mentioned as a causative factor for lung cancer among uranium miners. Yet from 1869 to 1878, well before the diesel engine was patented in 1892, lung cancer caused 75 percent of miner deaths at Schneeberg (Ha79). The observation of excess lung cancer mortality in workers in a variety of hard rock and metal mines indicates that uranium ore dust is not critical to the development of lung cancer

(Fr48, Hu66, Lu71). The only common factor identified in all miner groups studied is the presence of radon and radon-daughter aerosols in the respired air (Mi76).

The general recognition of the radon problem has resulted in a number of epidemiological studies in various countries, including the U.S.A., Canada, Czechoslovakia, Sweden, and Great Britain. Lung cancer deaths in U.S. uranium miners have been the subject of an extensive epidemiological study led by the U.S. Public Health Service (Lu71, Ar74, Ar76), which has provided much information on the etiology of radiation-induced lung disease. Nevertheless, this study and to a lesser extent other studies of cancer deaths among underground miners have limitations when used for the purpose of providing risk estimates applicable to the general population. The relative importance of these limitations has been considered in the risk estimates made below.

The estimates of the risk to miners have continued to rise as more epidemiological data have accumulated. In this regard it is of interest to compare recent information on radiogenic lung cancer with that available in 1970-1971 when the Federal guide for occupational exposure of miners was reduced from 12 to 4 Working Level Months (WLM) per year (Fe71). These guides were based almost exclusively on the experience of U.S. uranium miners exposed to high concentrations of radon daughters. At that time 70 lung cancer cases had been observed in the study group. While this number of cases exceeded the expected number of 12, about half of the cancers followed exposures of more than 1800 WLM (Lu71).

Figure 5 shows the number of lung cancer cases observed in the U.S. uranium miner study group through September 1968, and their estimated levels of exposure in WLM. The expected number of deaths depends on the number at risk at each dose level and is based on white males in the four western states where the uranium mines were in operation (Lu71). Three things are worth noting in these early results: the small number of deaths in each broadly defined exposure category, the relatively constant ratio of expected-to-observed deaths below 1800 WLM, and finally the absence of any significant difference below 120 WLM. For these reasons alone, it is easy to appreciate why early estimates of the risk due to radon inhalation were controversial; there was essentially no dose response information available. More recent data, described below, differs considerably from these 1968 results.

A fundamental limitation in this and similar investigations of lung cancer mortality is that the U.S. study is still in progress. Survivors in the U.S. study are continuing to die of lung cancer with the result that more recent data show a much larger number of lung cancer deaths than was originally projected (Na76). Another very serious limitation, peculiar to the U.S. study, is that the cumulative exposures to the 4000 workers involved were quite large, averaging

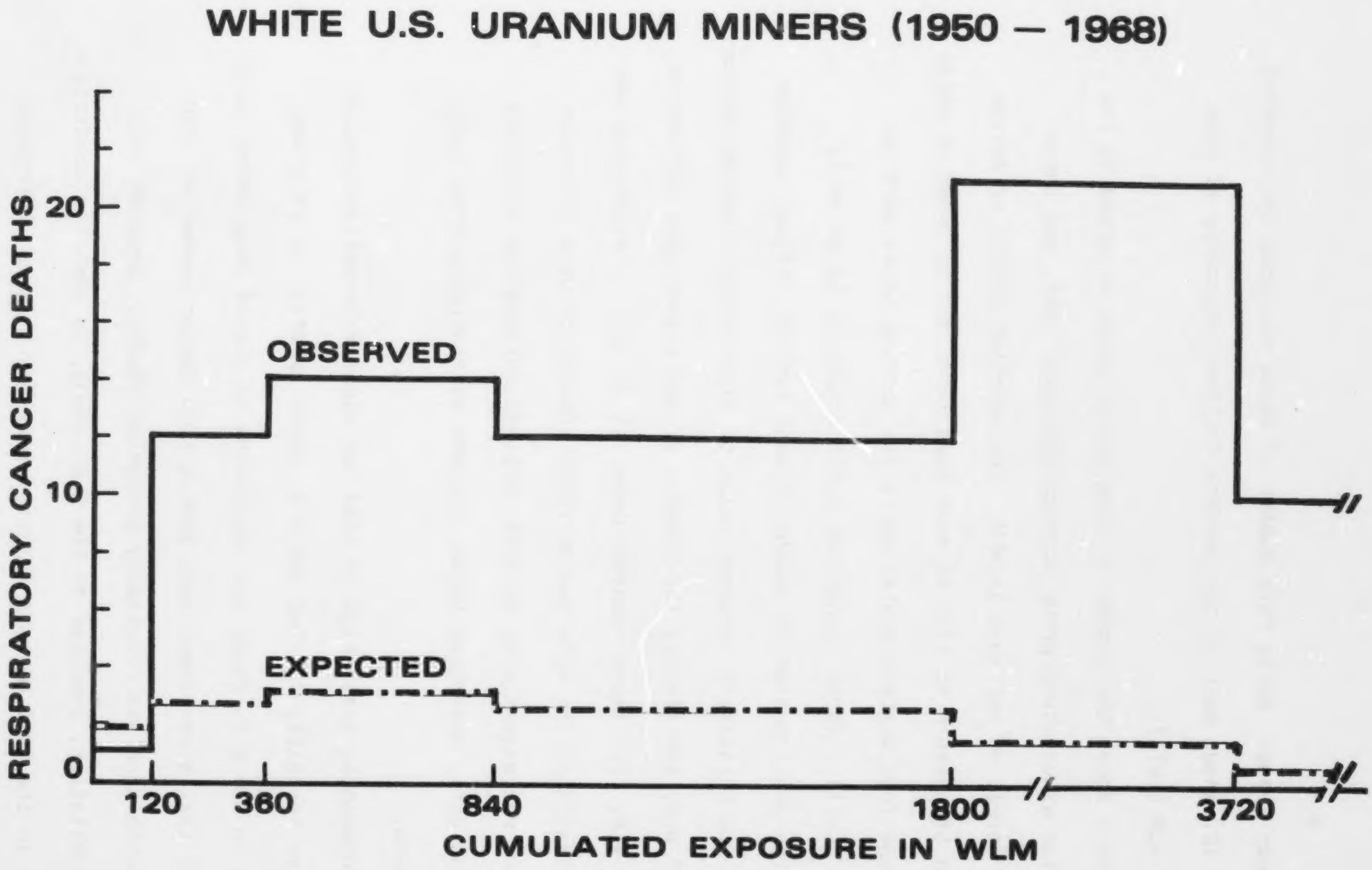

Figure 5. RESPIRATORY CANCER MORTALITY REPORTED FOR U.S. URANIUM MINERS (Lu 71). SEE TEXT FOR LIMITATIONS ON DATA

nearly 1000 WLM per miner. There is some evidence that at such high levels of exposure the risk per unit exposure is somewhat less than occurs at radon daughter exposures below a few hundred working level months (Lu71, Na76). In addition, the lung cancer mortality data for Japanese atomic bomb survivors also shows a trend for increasing lung cancer risk per unit dose at lower doses (Un77). For this reason it is advisable in risk analysis to limit the use of epidemiological data for miners to that obtained at moderate exposure levels, i.e., a few hundred working level months.

The limited information available from the study of the U.S. uranium miners can be augmented by using results derived from epidemiological studies of miner health in other countries and in other types of mining operations. The occupational environments in these mines differed substantially from those in the U.S. underground uranium mines so that the cumulative exposure from radon decay products was much smaller (Mi76, Se76, Sn74). In addition, the reported follow-up period in some of these studies is longer than for the U.S. study population. In all study groups, however, some miners are still alive and the final number of lung cancer cases is expected to be larger. The absence of data from completed lifetime follow-up studies can lead to a biased underestimation of the risk due to the inhalation of radon daughters, unless appropriate risk models are utilized which recognize that current studies have not been completed. This important topic is discussed below.

The direct proportionality of cancer risk to radon decay product exposure at levels likely to be experienced in the environment cannot be demonstrated for either human populations or by animal studies because of the large number of subjects needed. As shown below, the available data indicate that the use of a linear response curve for humans exposed to low concentrations of radon decay products is not expected to greatly overestimate or underestimate their cancer risk provided that the exposures do not exceed a few hundred working level months. Figure 6 illustrates the observed cancer excess in Canadian uranium miners who were exposed to much lower concentrations of radon decay products than are common in U.S. uranium mines, (c.f. Figure 5). Although this study may not be fully adequate to establish a quantitative estimate of the risk per working level month because data on smoking histories is incomplete, these data have been shown to be consistent with a linear dose response relationship at relatively low levels of exposure and strongly argue against a threshold dose for radiocarcinogensis in the lung (Mi76).

Figure 7 shows results obtained by J. Sevc and co-workers, from their study of uranium miners in Czechoslovakia whose mining experience started after 1948 (Se76). In that country, excess lung cancers had been observed in uranium miners exposed before World War II. An appreciation of this led to better ventilation of the uranium mines and resulted in relatively low levels of exposure to miners entering the work force after 1947. The average follow-up period in this

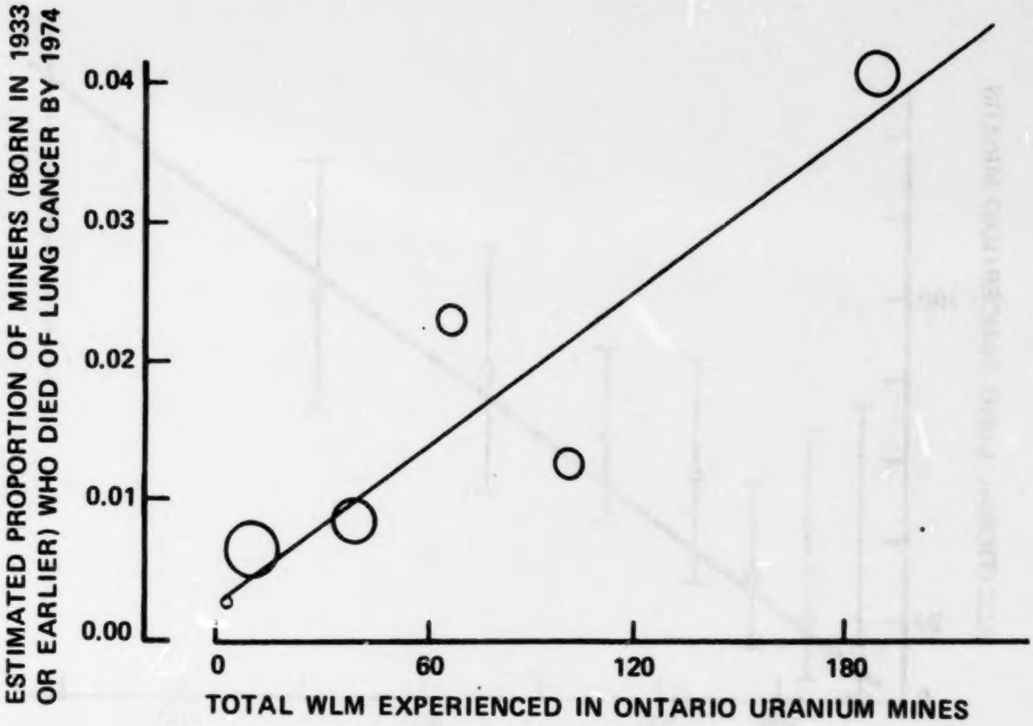

Figure 6. Respiratory Cancer Mortality in Ontario (Canada) Uranium Miners (Mi 76)

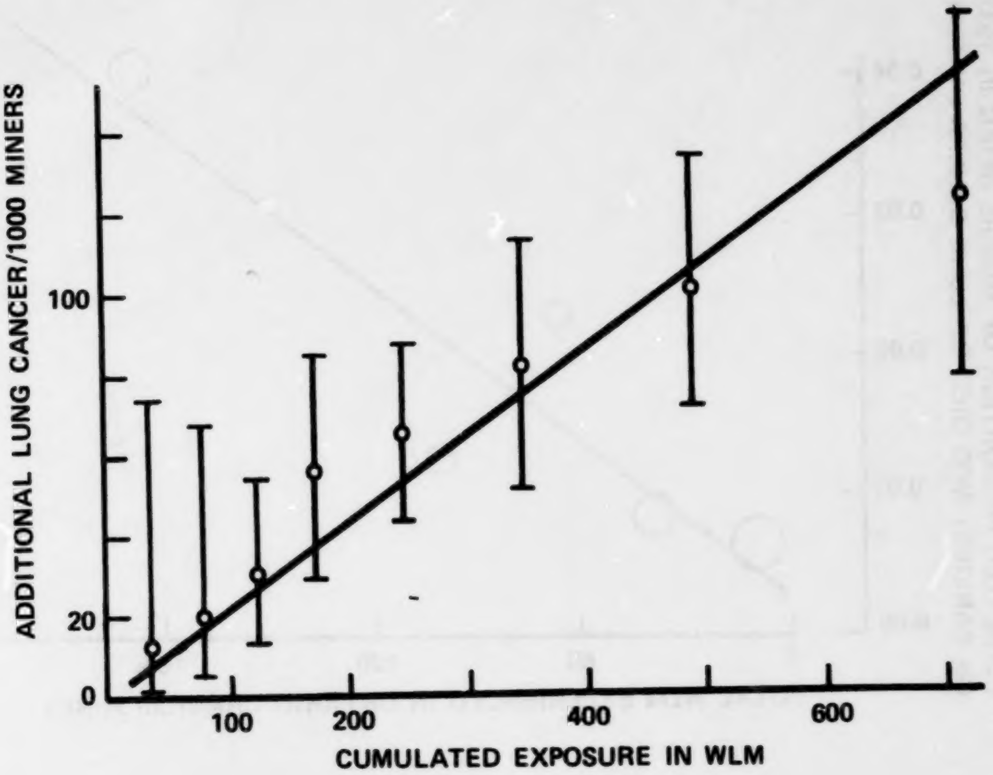

Figure 7. Respiratory Cancer Mortality Reported in Czechoslovakian Uranium Miners (1948 - 1972). Average for all ages, (See text), (Se 76)

group is twenty three years. The high degree of correlation between exposure and excess cancer shown represents an overall average for workers of various ages. This study also found that the absolute cancer risk increased substantially with the age at which a worker entered this work force.

It should be noted also that epidemiological data of the kind illustrated in Figures 6 and 7 will always overestimate the exposure to radon decay products needed to initiate a lung cancer. The exposure considered in these studies is that accumulated throughout the working life of these miners. The dose received but ineffective in producing cancer between the period of cancer initiation and its manifestation is not discounted. For chronic exposure, the same reasoning applies to determining the minimum exposure level at which a significant number of cancers occur; an apparent threshold dose will exist, unless the cancer is initiated on the last day of exposure.

4.1.2 Risk Estimates for Underground Miners

Estimates of the cancer risk due to the inhalation of radon decay products can be made either on the basis of the dose delivered to the basal cells of the bronchial epithelium or the cumulative exposure in WLM. In 1972 the NAS-BEIR Committee used the former method to prepare their risk estimates so that other types of ionizing radiation could be considered also (Na 72). More often estimates of the risk due to radon decay products are based on the cumulative exposure in WLM (Lu71, Ar76, Na76, Un77, Mi76, Se76, Sn74).

The dose to the bronchial epithelium has been calculated by several investigators (Wa77, Ha74, Ha72). While valuable, these studies indicate that the dose (in rads) is highly dependent on a number of factors which have varying degrees of certainty. One important, but as yet poorly known, parameter is the depth below the mucosal surface at which the sites in irradiated tissues giving rise to lung cancer are located. This distance, which is likely to differ in various portions of the respiratory tract, is not known with any accuracy. In addition, no information is available on the degree of uniformity of deposited daughter products in various parts of the bronchial tree. Furthermore, the _in situ_ absorption and removal pattern of the radon decay products lead-214 and bismuth-214 is poorly understood. Recent experimental evidence indicates that to postulate their complete decay in the mucus near the bronchial epithelium, as is usually done, is likely to be in error (Ja77). Because of the uncertainty in calculated doses, the Agency prefers to base estimates of the risk due to radon decay products on the cumulative exposure in working level months.

The 1972 NAS-BEIR Report used two types of analyses in estimating the radiation-induced cancer risks from follow-up studies of exposure groups (Na 72). One, called the absolute risk estimate, is the numerical increase in the number of excess cancers per unit of exposure, averaged over all age groups. The other, the relative risk estimate, is the estimated percent increase in excess cancer per unit exposure

Either of these models will yield the same number of excess cancers for a given study population if based on data from a lifetime follow-up period. Because exposed persons have been followed for a shorter duration, a choice between these models is needed. In the exposed groups studied, the risk of radiogenic lung cancer, but apparently not all cancers, increases with the participants age in about the same manner as the "natural" incidence of lung cancer, i.e., the relative risk remains constant. In contrast, the absolute risk estimates derived from the U.S. study are not constant but have continued to increase as the length of the follow-up period is increased (Na76). Lung cancer mortality among Japanese survivors has shown a similar pattern (Be77). Moreover, analysis by age shows the Czechoslovakian and Canadian lung cancer data to be grossly inconsistent with the absolute risk hypothesis (Mi76, Se76).

More recently, the Japanese cohort data on lung cancer mortality for those exposed to high LET bomb radiation at age of 50 or more have been examined for the time of occurrence of excess lung cancer after exposure (La78). Because of their age, a near lifetime follow-up study of this group is possible; the youngest surviving member was nearly 80 at the time of the study. Lung cancer mortality was compared for two dose ranges, those highly exposed, where three times the expected number of cancers was observed, and a control group receiving 0 to ten rads ("tissue kerma" in air). The time to occurrence of the lung cancers is the same for the two groups, as would be expected if the increase in lung cancer mortality follows the temporal pattern predicted by a relative risk model. This is similar to observed patterns of lung cancer observed in animals following plutonium inhalation (Na 76). In the analysis of these data as they apply to human health risks the 1976 NAS Report stated, "as already indicated, the steepness with which lung cancer death rates in the Battelle (Northwest Laboratory) beagles rose as a function of age strongly suggests that the relative risk estimate is the appropriate one to use in the present context of assessing lung cancer risk from alpha emitters." For these reasons, relative risk estimates are thought to provide a better projection of the risk of lung cancer than absolute risk estimates. However, both types are included in the set of risk estimates made below.

As an alternative to these two models, an age-dependent absolute risk model with age-dependence somewhat different from that for natural cancer incidence would also be compatible with the observations made on uranium miner populations. It should be noted that the estimated risks using such a model would be much closer to those calculated on the basis of relative risk than for an age-independent absolute risk model. As yet, parameters for age-dependent lung cancer risk models have not been published.

The estimate of the absolute risk due to exposure to radon decay products in the general environment contained in this report are based on recent mortality experience of U.S. uranium miners (Na76). Comparable U.S. data on relative risk are not available, the most recent relative risk compilation was in 1972 for the NAS-BEIR report

(Na72). Since that time, enough new cancers have occurred so that absolute risk estimates based on this group have more than doubled (Na76). The effect of this longer follow-up period on their relative risk is unknown, but may be substantial. Therefore the estimates of relative risk made here are based on studies of underground miners in Czechoslovakia and Sweden. Relative risk data for the Ontario miners have not been published. However, an oral presentation indicates the results of the Ontario study (Mi76) agree with those for Czech and Swedish miners (He78).

The percent increase in excess cancer per WLM for Czechoslovakian uranium miners is shown in Table 6. These data have been recalculated

TABLE 6

OBSERVED INCREASE IN LUNG CANCER FATALITY RATE CZECHOSLOVAKIAN URANIUM MINERS

Mean Exposure (WLM)	% Increase per WLM
39	3.6*
80	1.0*
124	1.6
174	2.9
242	2.2
343	2.0
488	1.8
716	1.4

*Not significant at the 5% level of confidence from References Se73 and Se76 on the basis of an assumed nine-year latent period between the start of exposure and the occurrence of a radiation-induced lung cancer. At the exposure levels which occurred in the Czech uranium miners, the average risk would appear to be increased by about 2-3 percent per WLM.

Table 7 shows the percent increase per WLM observed in Swedish miners (Sn74, Ra76). In this case the increase may be as great as 4 percent per WLM at lower levels of exposure. The variations in the percent increase in lung cancer found in these epidemiological studies are not due to statistical sampling variation alone. Each study reflects differences in the age distribution of those exposed, the duration of the exposure, and the follow-up periods. Given the variations shown in Tables 6 and 7, the best that can be done is to propose a range within which the actual risk may lie, as described in Section 4.1.3.

TABLE 7

OBSERVED INCREASE IN LUNG CANCER FATALITY RATE
SWEDISH IRON AND ZINC MINERS

Mean Exposure (WLM)	% Increase per WLM
15	4*
48	4.2
218	3.3
696	2.5

*Not significant at 5% level.

4.1.3 Applicability of Underground Miner Risk Estimates to the General Population

As in most cases where the results of epidemiological studies of occupational exposures are applied to the general population, there is uncertainty in the extent of comparability between the persons at risk. Very little information is available on those non-occupationally exposed. A recent case control study by Axelson and Edling (AX79) is suggestive that the mortality per WLM for Swedish residents in homes having presumably high levels of indoor radon daughters is comparable to that observed in underground miners. However, the sample size is small and the exposure estimates too tentative to allow definite conclusions.

Since the only common factor in underground miners with increased risk of lung cancer mortality is exposure to radon and radon daughter aerosols, the comparability of mine atmospheres, indoor and outdoor, should be considered. Jacobi, et al., (Ja59), studied aerosol particle size distributions indoors, outdoors, and in radium mines, finding similar distributions in each place. Measurements by George (Ge75a), George, et al., (Ge75b) and others (Ha76, Lo77, Le75) would lead to similar conclusions. Holleman has also concluded that the difference between mine and atmospheric aerosol particle distributions was negligible, with the possible exceptions of the immediate vicinity of diesel engines and remote areas of the mine where aerosol concentrations were low (Ho68).

In general, mine atmospheres are not expected to differ greatly from environmental atmospheres of the same quality. Dusty atmospheres have low, unattached radon-daughter fractions, clean atmospheres have high unattached fractions. Well-ventilated areas have low radon-daughter ratios, poorly ventilated areas have high ratios. There is no feature which would uniquely identify either mine or environmental atmospheres, as shown in Table 8.

TABLE 8

Comparison of Typical Aerosol Characteristics

Aerosol	Ventilated Mines	Environment	
		Outdoors	Indoors
Activity Median Diameter (μm)	$0.17^{(a,b,c)}$	$0.04\text{-}0.30^{(e)}$	$0.10\text{-}0.20^{(a)}$
Concentration (particles/cm ^{3})	10^7 (drilling)$^{(c)}$ $10^3\text{-}10^6$ (c)	$10^4\text{-}10^5$ (a)	$10^4\text{-}10^5$ (a,f)
Uncombined Fraction (Range)	$0.04^{(c)}$ (0.002-0.12)	$0.08^{(a)}$ (0.005-0.25)	$0.07^{(a)}$ (0.003-0.20)
Radon-Daughter Ratio Range	1.0,1.0,0.4,0.3 (c) to 1.0,0.3,0.03,0.03	1.0,0.9,0.7,0.7 (a,d) to 1.0,0.8,0.5,0.3	1.0,0.8,0.8,0.7 (a,d,f) to 1.0,0.5,0.3,0.2

References:

(a) Ge75a
(b) Ge75b
(c) Ge72
(d) Ha76
(e) In73
(f) Lo77

There are several reasons for believing that the percent increase in lung cancer per unit exposure to a general population could be either more or less than that for miners. Alpha particles from radon daughters have ranges in tissue comparable to the thickness of the bronchial mucus and epithelium. The thickness of the bronchial epithelium of underground miners may be greater than is common in the general population. The BEIR Committee estimated that the shielding provided by the thicker epithelium of miners reduced their dose (and risk) per unit exposure by a factor of two compared to the general population (Na72).

On the other hand, miners' lung cancer mortality data reflect a high frequency of cigarette smoking which tends to increase their lung cancer risk relative to the general population. The degree to which smoking in conjunction with exposure to radon daughters may increase the incidence of radiation-induced lung cancer is not known. While a study of U.S. uranium miners has suggested a very strong association between cigarette smoking and radiation-induced lung cancer, the correlation between age and smoking history in this study precludes early judgment, particularly since the study also indicates that nonsmokers have a longer latent period for radiogenic lung cancers (Ar76). Some Swedish data on underground miners show that smoking may increase radiogenic cancers by a factor of about two to four (Ra76), however, these results may be dependent on the duration of follow up. Axelson and Sundell (Ax78) have reported that in a life span study of 19 exposed miners who died of lung cancer, the lifetime risk of lung cancer in non-smokers exceeded that of smokers. The latency period, however, was much shorter for smokers. A sample size this small, of course, precludes definitive judgments. Unfortunately, the Japanese data are, as yet, too imcomplete to yield comparable risk estimates for cigarette smokers or non-smokers or even by sex (Be77).

Smoking is common in all populations at risk from environmental radon. While the frequency of smoking in U.S. uranium miners was not very different from that of other male industrial workers at that time, it exceeds the current level of cigarette use, particularly by females (St76). It is not clear that this will be true in the future. Cigarette smoking among younger females is continuing to increase and may approach or exceed cigarette smoking by males. If so, relative risk estimates for exposure to radon daughters based on the current incidence of lung cancer mortality, which is now almost wholly due to male deaths, will be too low. Conversely, if cigarette smoking in the U.S. becomes less common for both sexes sometime in the future the incidence of lung cancer may decrease and relative risk estimates based on the current incidence will be too high. Clearly cigarette smoking is likely to be a factor in determining the probability that a lung cancer is induced by exposure to radon daughters. The Agency recognizes that estimates of the risk due to radon daughter inhalation have a wide range and may be too high or too low, depending, among other factors, on the prevelance of cigarette smoking in the future.

Based on Tables 6 and 7 and the considerations outlined above, the range of the fractional increase in lung cancer due to radon decay products in the general environment is thought to lie between one and five percent per WLM. Studies utilizing longer follow-up times and relatively low exposures tend to support the latter figure. However, if miners are atypically sensitive to radon daughters because of other characteristics in their occupational environment the fractional increase for the general population could be as low as one percent per WLM or less.

Another characteristic of the population at risk that differs from underground miners is age. The estimated risk for miners is averaged over adult age groups only, children not being at risk. It is assumed in the absolute risk estimates given below that the risk due to radon daughters is the same for children as adults. While this has little effect on the estimates of risk made with an absolute risk model, relative risk estimates are more dependent on the assumed sensitivity of children to radiation. The Japanese experience, as reported in the 1972 BEIR Report, indicates that children irradiated at the age of nine or less have a relative risk rate of fatal solid tumors ten times that of adults (Na72). However, none of the observed cancers in this group has been lung cancer, a cancer of old age. (There is, of course, no information on lung cancer due to occupational exposure of children to radon decay products.)

The Agency believes that while it may be prudent to assume some allowance for the extra sensitivity of children, the factor adopted should be less than a factor of ten. Therefore, in the Tables below, a three-fold greater sensitivity for children is assumed in some of the relative risk calculations of mortality due to inhaled radon decay products.

Cumulative exposures for a given concentration of radon daughters differ between miners and the general public. For radon decay product exposures occurring to nonoccupationally exposed persons, consideration must be given to the fact that the breathing rate (minute-volume, etc.) of miners is greater and the number of hours exposed per month less than in the general population. Radon decay product exposures to underground miners are calculated on the basis of a working level month (defined as exposure for 170 hours to one working level). Exposure to radon daughters in the general environment occurs for an average of 730 hours per month. The breathing rate over this period of time is less than an average breathing rate appropriate for underground miners engaged in physical activity. Assuming that the average underground miner (comparatively few of whom work at the mine face) is engaged in a mixture of light and heavy activity throughout the working day, his monthly intake of air on the job is about 3×10^5 liters (In 75). An average man (reference man) is assumed to inhale 2.3×10^4 liters per day (males) or 2.1×10^4 liters per day (females) (In 75). The average intake for both sexes is 6.7×10^5 liters per month, 2.2 times more than for miners at work. Therefore, an annual exposure to 1 WL corresponds to nearly 27 WLM for exposures occurring in the general environment.

In the case of radon in residential structures, the time the residence is occupied must be considered also. On the average, Americans spend about 75 percent of their time in their place of residence (Mo76) so that about 5 x 10^5 liters of residential air is inhaled each month. This corresponds to about 20 WLM per year for a radon decay product concentration of 1 WL in residential structures. Children respire a greater volume of air relative to the mass of irradiated bronchial tissue than do adults, so that their exposure to radon daughters is almost a factor of two greater for a few years (In75). This increase has been included in the Section 4.1.4 risk estimates.

4.1.4 Risk Estimates for the General Public

Estimates of cancer risk in this report have been derived from an analysis that considers the following factors: the competing risk from causes of death other than radiation, the fractional and absolute increase in lung cancer per unit exposure, the duration of the exposure, the period between the time of exposure and the occurrence of a clinically identifiable cancer (latency), and the length of time a person is at risk following the latent period (plateau period) (Bu78). The risk estimates below assume a fixed latent period of 10 years for lung cancers (Na76). Although there may be some correlation between latency and age, relative risk estimates are not too sensitive to this parameter. Increasing the latency period to 30 years reduces the estimated risk by between 20 and 40 percent depending on the sensitivity assumed for children. In the case of lung cancer, it is assumed that following the latent period an individual remains at risk for the duration of his or her lifetime. While for some cancers a shorter plateau at risk may be appropriate, the U.S. miner data as well as the Japanese bomb survivor data reflects a continuing increase in radiogenic lung cancers beyond 70 years of age.

In these risk estimates it is assumed that the population at risk is subject to lifetime exposure and the distribution of ages is that in a stable (stationary) population (Un75). The Agency recognizes that residential dwellings are seldom occupied by one family group for their lifetimes. However, this has little effect on the ultimate health impact if another family occupies the structure. The health risk to a particular family is a function of the time they occupy the dwelling and to a lesser extent their ages. For most practical purposes, the risk due to occupancy of less than 70 years can be found by taking a fraction of the risk given below as proportional to the years of occupancy. For example, 7-year occupancy would be expected to yield one-tenth the estimated risk of lung cancer due to lifetime exposure, approximately 70 years. Residences which serve primarily as children's or geriatric's homes would be obvious exceptions.

The excess cancers due to radiation change the cause of death and the age at which death occurs in the population at risk. The EPA analysis provides estimates of the number of premature deaths, the number of years of life lost per excess death, and the total number of years of life lost by the population at risk. These parameters are included in the risk estimates presented below.

Based on the assumptions discussed above, Table 9 lists the estimated number of premature fatalities due to lung cancer that may occur in a population of 100,000 persons occupying structures having a radon decay product concentration of 0.02 WL. The total number of years of life lost by the population at risk is also tabulated. These estimates are based on relative risk models which assume a 3 percent increase in lung cancer per WLM. Two cases are compared in this Table: (1) that adults and children have the same sensitivity, and (2) that children below the age of ten are three times more sensitive than adults. It is seen that the latter assumption increases the estimated risk by about 50 percent.

Table 9

Estimated Risk of Lung Cancer Per 100,000 Exposed Individuals Due to Lifetime Residency in Structures Having an Average Radon Daughter Concentration of 0.02 WL Relative Risk Model*

	Excess Cancer Deaths	Total Years Lost
Child Sensitivity = Adult	2,000	30,000
Child Sensitivity = 3 x Adult	3,000	50,000

*Assumed mortality 3 percent per WLM (see text)

Table 10 presents absolute risk estimates for a radon decay product concentration of 0.02 WL and lifetime exposure. This Table has been calculated on the assumption that absolute risks are independent of the age at which exposure is received. The estimate of the number of years of life lost, compared to the relative risk for the same age sensitivity, is about the same, c.f. Tables 7 and 8. The estimated number of excess fatalities is a factor of two less than that estimated using the relative risk model. This is within the uncertainty of the relative risk estimates since the range of values for the percent increase in lung cancer per WLM is between 1 and 5 percent per WLM, vis a vis the 3 percent increase assumed in Table 10.

Table 10

Estimated Risk of Lung Cancer Per 100,000 Exposed Individuals
Due to Lifetime Residency in Structures Having An Average
Radon Daughter Concentration of 0.02 WL
Absolute Risk Model*

	Excess Cancer Deaths	Total Years Lost
Child Sensitivity = Adult	1,000	27,000

*The assumed risk coefficient is 10 excess lung cancer deaths per WLM for 10^6 person years at risk (Na 76).

For comparison purposes, it is of interest to estimate the number of excess lung cancers in the U.S. due to ambient levels of radon decay products in non-contaminated areas. The concentration of radon decay products in structures has not yet been surveyed extensively. Most measurements reported in the literature are for either a short duration, i.e., single samples, or in contaminated areas. An exception is the long-term radon measurement program of the Environmental Measurements Laboratory in the Department of Energy. Their measurements of radon decay products indicate average background levels in residences of 0.004 WL (Ge 78). An ambient indoor background of this level yields calculated risks one-fifth of those shown in Table 9, i.e., from about 400 to 600 cases. This is about 10 to 20 percent of the expected total national lung cancer mortality of 2900 per 100,000 in a stationary population having the 1970 U.S. mortality rates. This percentage of lung cancer mortality is not necessarily attributable to radon exposures alone, since many cofactors have been implicated in the etiology of lung cancer. It is emphasized that these risk estimates are not precise and that the actual risk from radon daughter exposures could be a factor of two or more larger or smaller.

It should also be noted that the risk estimates made here are based on a risk analysis using U.S. national health statistics. They have not been adjusted for the age, sex, or other demographic factors pertinent to persons living on phosphate lands in Florida. To the extent that the incidence of lung cancers in these areas is higher by about 40 percent than the national average, the estimated health impact of radon exposures given above may be low in Florida residents. In contrast, the persons living on phosphate lands could have demographic characteristics which differ from the national average in such a way as to lower their risks compared to those listed above. For example, if the housing were used primarily by the very old, there would be appreciably less health impact.

4.2 The Health Risk Due to External Radiation Exposure

Unlike the highly ionizing alpha particles from radon daughters, external radiation exposures are due to lightly ionizing secondary particles from interactions along the path of gamma-ray penetration. High energy gamma-rays penetrate through the body causing a relatively uniform exposure to all tissues and organs. Since all organs and tissues are exposed, the complete spectrum of cancers outlined in the

1972 NAS-BEIR Report (Na72) would be expected. In addition, some genetic risk, resulting from irradiation of the gonads, would be expected to occur.

In the case of external penetrating radiation, data presented in the 1972 NAS-BEIR Report (No 72) yields the following estimates for lifetime whole body exposure to 100,000 persons as shown in Table 11.

TABLE 11

Estimated Lifetime Risk of Excess Fatal Cancer and Genetic Abnormalities Per 100,000 Individuals Exposed to an Annual Dose Rate of 100 mrem

	Excess Fatal Cancers	Total Years Lost
Relative risk	470 a) 150 b)	6500 a) 2700 b)
Absolute risk	84 a) 68 b)	1900 a) 1700 b)

a) life time plateau b) 30 year plateau

Serious genetic abnormalities*

1st generation	all succeeding generations
2-40	10-200

*Birthrate 2% per year

These estimates are based on the assumption that the number of health effects observed at relatively high doses and dose rates can be extrapolated linearly to the low levels of radiation usually found in the environment. Table 11 lists only fatal cancers. The 1972 NAS-BEIR Committee has estimated that a comparable number of non-fatal cancers could be induced also.

External exposure to natural background radiation in Florida, from both cosmic radiation and radiation from radioisotopes present in the soil, is about 59 millirem per year, except in regions containing anomalous sources. The estimated lifetime risk associated with this background is therefore about 60% of the values listed in Table 10.

SECTION 5.0

ANALYSIS OF CONTROL ALTERNATIVES

5.1 SUMMARY OF AVAILABLE CONTROL MEASURES[*]

There are five major types of radon decay product control measures. These are categorized in Table 12 as to their efficacy for application to existing or planned structures. For existing structures, air cleaners and polymeric sealants have been shown to be efficient at either reducing radon decay product levels in the structure or radon diffusion through the foundations, respectively. The cost range for these measures is $900-2600 (assuming an average cost of $1200 for sealant application). These cost values are based on the sum of capital cost, plus future maintenance charges and operational costs reduced to their present worth, the discount factor being 6 percent per year over 70 years, the assumed lifetime of the average structure. For planned structures, design measures could include ventilated crawl spaces, excavation and fill, and improved slab construction. As a result of these measures, radon diffusion can be reduced before it enters the structure's atmosphere by venting or reduction of the parent radium concentration. Total costs for implementing these measures vary from $550 (for crawl space construction) to $5500 (for excavation and fill). As these are all

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[*] A more detailed treatment of the subject can be found in Appendix C.

TABLE 12

ESTIMATED AVERAGE COST OF CONTROL MEASURES FOR STRUCTURES CONSTRUCTED ON FLORIDA PHOSPHATE LAND*

CONTROL MEASURE	CAPITAL COST	ANNUAL MAIN-TENANCE COST	ANNUAL ELECTRICAL COST	TOTAL AVG. ANNUAL OPERATING COST	PRESENT WORTH OF TOTAL COST (70 YRS)
EXISTING STRUCTURES					
AIR CLEANERS:					
HEPA	$400	$100	UNDEFINED**	$100	$2050
ELECTRONIC	$350	$25+ ***	$10	$35+	$900
ELECTRONIC AND AIR EXCHANGER	$900	$25+	$80	$105+	$2600
POLYMERIC SEALANT:	$600-$1950	UNDEFINED**	NONE	NONE	$600-$1950
PLANNED STRUCTURES					
VENTILATED CRAWL SPACE:	$550	NONE	UNDEFINED**	NONE	$550
EXCAVATION AND FILL: (TO 10' DEPTH)					
COMMERCIAL FILL RATE –					
FOR 80% RADON REDUCTION (INCLUDES 99% GAMMA)	$3250-$5500	NONE	NONE	NONE	$3250-$5500
FOR 80% GAMMA REDUCTION	$250-$400	NONE	NONE	NONE	$250-$400
W/NOMINAL FILL COST –					
FOR 80% RADON REDUCTION (INCLUDES 70% GAMMA)	$2550-$2900	NONE	NONE	NONE	$2550-$2900
FOR 80% GAMMA RED	$200	NONE	NONE	NONE	$200
IMPROVED SLAB CONSTRUCTION:					
FOR 80% RADON REDUCTION (INCLUDES 70% GAMMA)	$550	NONE	NONE	NONE	$550
FOR 80% GAMMA REDUCTION	$600	NONE	NONE	NONE	$600

*ASSUMMING 1500 SQUARE FEET FLOOR AREA AND 1977 DOLLAR VALUE (6% DISCOUNT PER YEAR APPLIED); ALL FIGURES ARE FOR RADON PROGENY REDUCTION EXCEPT WHERE OTHERWISE NOTED

**SEE TEXT

***"+" SIGNIFIES THAT THE ESTIMATE GIVEN IS MOST LIKELY A MINIMAL ONE, ALTHOUGH THE ACTUAL AVERAGE IS UNDEFINABLE USING AVAILABLE COST DATA passive measures (i.e., having no maintenance or operational requirements), the total cost involved consists solely of the capital cost of implementation (although there may be minor exceptions such as additional heating cost due to increased infiltration of air and heat conduction through the floor for a crawl space compared to an on-grade slab).

The control measures listed in Table 12 have been field tested on a limited basis in a number of locations in this country and Canada. In the Grand Junction (Colorado) remedial program, for example, sealants, excavation and fill, and electrostatic precipitators were used to reduce indoor radiation levels pursuant to the Surgeon General's Guidelines (see page 77). While the latter two methods achieved reduction efficiencies at or near 80 and 40 percent, respectively, results from application of sealants proved inconsistent. Experience by the Canadian authorities (At78, Fi78) in applying sealants to structures constructed on radium-contaminated soils, however, suggests that this lack of consistency in achieving desired reduction is likely due to inadequate sealing of existing conduits for radon into the structure's atmosphere. Their objective of achieving indoor radon decay product level reduction down to .02 WL (including background) was largely met by a combination of sealant application and removal of these major radon pathways in the foundation.

Although none of the radon decay product measures have been field tested in Florida, on the basis of their demonstrated efficiencies in these field programs, all of these measures should have an efficiency of about 80 percent, with the exception of electronic air cleaners (40 percent), when employed in normally ventilated structures. The lack of field confirmation is a drawback in determining the cost-effectiveness for each control. Regardless of this uncertainty, however, the cost figures are considered representative and permit a preliminary evaluation of cost-effectiveness.

Control of gamma exposure in existing structures requires either the addition of shielding or removal of the radium source from under the structure. Both of these procedures are quite expensive, with an estimated cost of 15 to 20 thousand dollars per structure. For gamma exposure reduction in planned structures, improved slab construction (i.e., additional slab thickness) should be about 80 percent effective for an additional four inches of concrete at an average cost of about $600. However, if clean fill at minimal or no cost is available, a comparable reduction in exposure may be possible at lower cost.

5.2 COST-EFFECTIVENESS

Control cost-effectiveness is defined as the ratio of the present worth of the cost of control to the reduction in health risk anticipated. The upper limit of acceptable cost-effectiveness is a value judgment on the maximum rate of spending that is justified for averting human health effects. While a detailed discussion of this issue is outside the scope of this document, such determinations have been made in other guidance issued by the Federal government. In the Uranium Fuel Cycle Standard (40CFR190), for example, a limit on reasonable cost-effectiveness ranging from $200,000-500,000 per health effect averted was used. While not necessarily applicable to the Florida case, this example provides some perspective concerning reasonable limits on acceptable values of cost-effectiveness.

5.2.1 General

As previously noted, two general categories of remedial measures are involved: those for existing structures which have been constructed on radium-bearing soil and those for structures which may be so sited in the future. These are important distinctions (as discussed further in Appendix C) because different types of controls have different costs and effectiveness depending on whether they are applied prospectively or retrospectively. Therefore, this examination of control cost-effectiveness is divided into four parts: radon decay product controls for existing structures, radon decay product controls for new structures, external gamma exposure controls for existing structures, and external gamma exposure controls for new structures.

In making estimates of the cost-effectiveness of various control technologies, the following assumptions were used:

1) The average dwelling has 1500 square feet of slab foundation.

2) It is occupied 75 percent of the time by a statistical average of 3.5 people.

3) Control costs are summed for a 70 year period, the assumed lifetime of the structure. While this may not be quite appropriate for existing structures, it does not significantly change the results because the costs of most controls are dominated by their capital cost. Further, the present worth of any annual costs beyond 20 or 30 years becomes negligible.

5.2.2 Control of Radon Decay Products

As previously estimated, the "normal" background radon decay product level in a Central Florida dwelling is about .004 WL. A structure which exhibits an indoor radon decay product concentration of .030 WL is thus about .026 WL above normal. The discussion on control technology effectiveness in Appendix C indicates that an average 80 percent reduction in the average indoor radon decay product level could be attained using one or more of the control methods listed. For this assessment it is assumed that the 80 percent reduction only applies to radon decay product air concentrations in excess of "normal" background. In many cases "normal" background radon decay product concentrations would probably also be reduced by applying these controls, but such potential reductions are not included in this evaluation of cost-effectiveness. If they were to be included they would tend to decrease the resource expenditures per health effect averted, making the application of the control more cost-effective.

Applying remedial measures to a structure exhibiting an average indoor radon decay product air concentration of .026 WL above normal (0.03 WL gross) is estimated to typically result in reducing the average concentration to about .005 WL above normal (.009 WL gross). The cost-effectiveness of taking this control action (based upon the health risk estimates in Section 4) is estimated as follows:

- estimated risk of lung cancer per 100,000 exposed due to lifetime residency at .03 WL = 3000 premature deaths (child sensitivity = adult)
- estimated risk of lung cancer per 100,000 exposed due to lifetime residency at .009 WL = 900 premature deaths (child sensitivity = adult)

Therefore, by reducing the level from .03 to .009 WL, an estimated 2100 lung cancer cases per 100,000 exposed are avertable. This is normalized to one structure assuming an average occupancy of 3.5 individuals to yield .074 averted lung cancer cases per structure.

From Table 12, the cost for controls ranges from $900 to $2600 per structure. Therefore, the cost-effectiveness is:

$$\frac{\$900\text{-}\$2600\text{/structure}}{.074 \text{ premature deaths averted/structure}} = \begin{array}{c}\$12{,}000 \text{ to } \$35{,}000 \text{ per} \\ \text{premature death averted}\end{array}$$

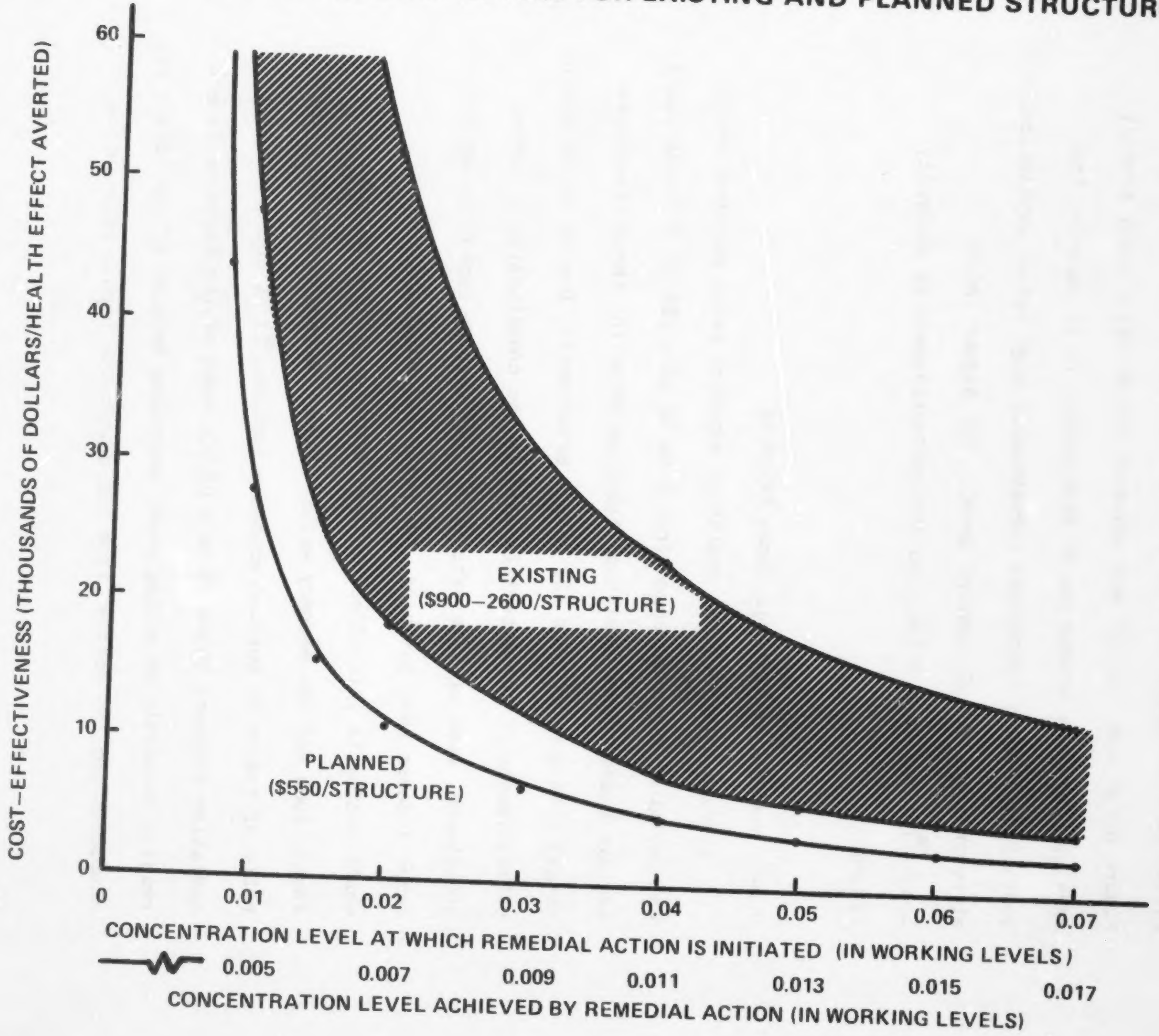
The above analysis was performed for various indoor radon decay product concentrations for both existing and proposed structures, (the latter at a projected cost of $550 per structure), and graphed in Figure 8 for both initial and achieved indoor radon decay product levels. For both categories of structures, it is apparent that cost-effectiveness approaches unreasonably high values asymtotically at roughly the .01 WL control level. For higher indoor concentrations, the calculated cost-effectiveness is generally favorable.

5.3.3 Control of External Gamma Exposure

Average outdoor gamma radiation exposure rates measured around the dwellings studied ranged from 3 to 42 μR/h (26 to 370 mrem/year). Average indoor gamma radiation exposure rates for these structures ranged from 3 to 27 μR/h (26 to 240 mrem/year). Due to the shielding effectiveness of the materials used in the construction of these structures, most of them exhibited lower average radiation exposures rates indoors than outdoors. The principal shielding element contributing to this effect is the concrete used in the slab foundations and the masonry walls. Other factors influencing the ratio of indoor to outdoor exposure include: 1) at lower external radiation exposure rates (5 to 9 μR/h), much of the exposure is not readily reducible by adding floor shielding because of the cosmic ray component and the scatter from the ubiquitous normal radioactive

Figure 8

COST—EFFECTIVENESS OF REMEDIAL ACTION TO REDUCE INDOOR RADON DECAY PRODUCT LEVELS FOR EXISTING AND PLANNED STRUCTURES



surroundings, and 2) the construction material may contain significant concentrations of radioactivity which would offset any shielding reduction.

Precise calculation of the exposure reduction expected due to control measures, such as additional slab thickness or removal of contaminated fill under a structure, is complex. It depends upon the geometry of the structure, its material makeup, and the radioactive environment, all of which can be approximated using a general model.

Because the cost of achieving control of gamma exposure in existing and new (or prospective) structures is vastly different, two separate evaluations need to be performed. In estimating the control cost-effectiveness for new structures, the following general assumptions were used:

1. The structure type in question is slab-on-grade.
2. The normal external gamma radiation exposure rate is 6 μR/h.
3. The impact of shielding, specifically concrete, on exposure reduction was taken from Figure 9 (SC 74).
4. Practical control cannot reduce the exposure rate to below normal background (primarily as a result of unshielded contributions through the structure walls).
5. The reduction factors are applied only to the difference between the normal background and unshielded exposure rates in computing the impact of shielding.

While these assumptions lead to a simplistic model, there does appear to be sufficient agreement with the field data collected for

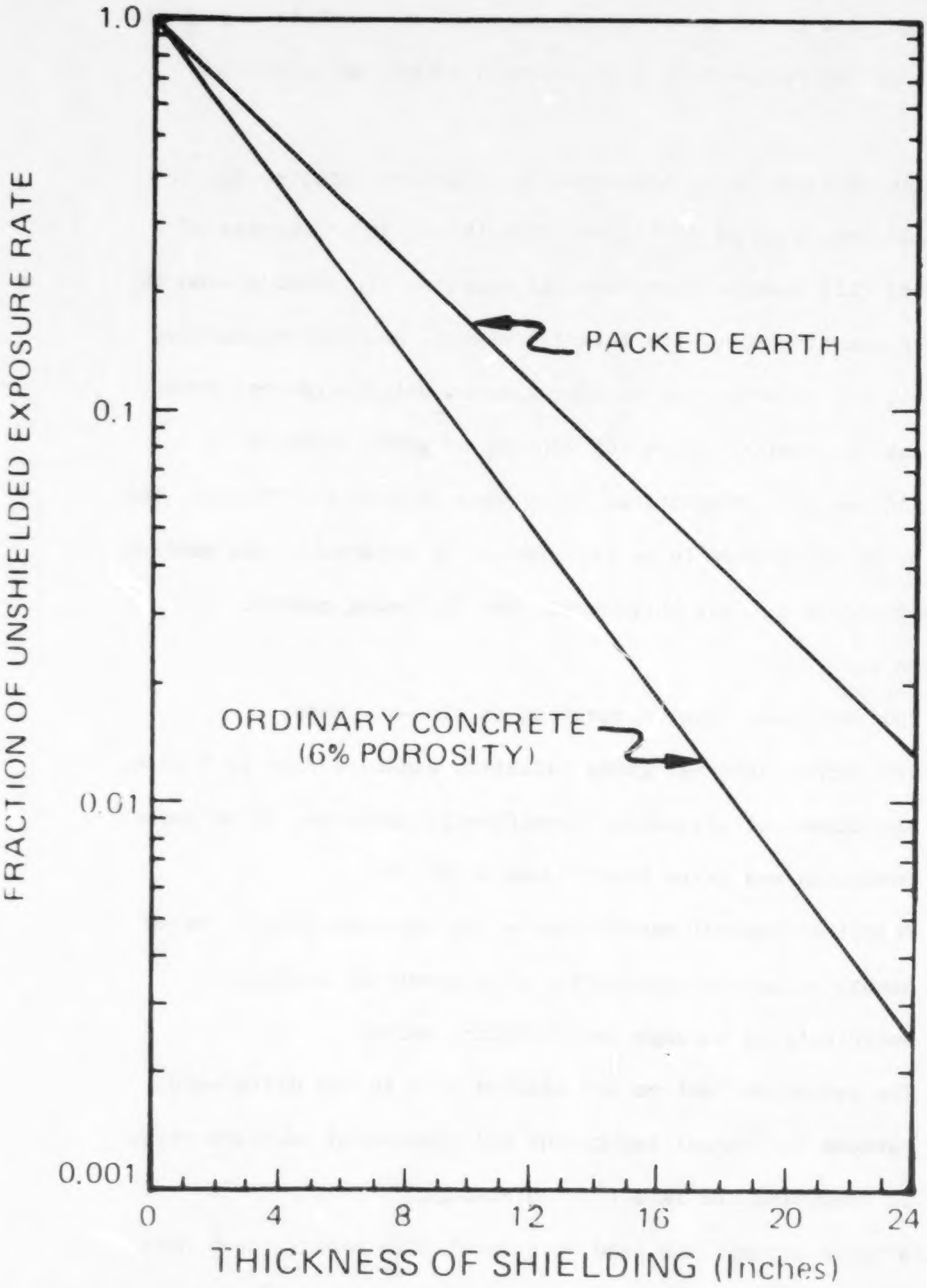


Figure 9. REDUCTION OF GAMMA EXPOSURE RATE RESULTING FROM EARTH OR CONCRETE SHIELDING (Sc 74)

slab-on-grade structures throughout the Central Florida study area as discussed in Appendix D and graphed in Figure 10. This is particularly true of structures originally exhibiting outdoor gamma exposure rates greater than 15 μR/hr. Therefore, it is anticipated that adding sophistication to the model would not markedly improve the usefulness of the analysis for decision making.

For new structures, the cost-effectiveness of controlling external gamma exposure is estimated as follows for a structure that is assumed to have an unshielded (i.e., external) exposure rate of 40 μR/h:

- A structure with a 4 inch shielding slab is estimated to have a gamma exposure reduction factor of 0.35 (Figure 9); therefore, the (model) residual indoor exposure is:

$$(40 - 6)\ \mu R/h \times 0.35 + 6\ \mu R/h = 18\ \mu R/h$$

Therefore, the net reduction is:

$$(40 - 18)\ \mu R/h = 22\ \mu R/hr;$$

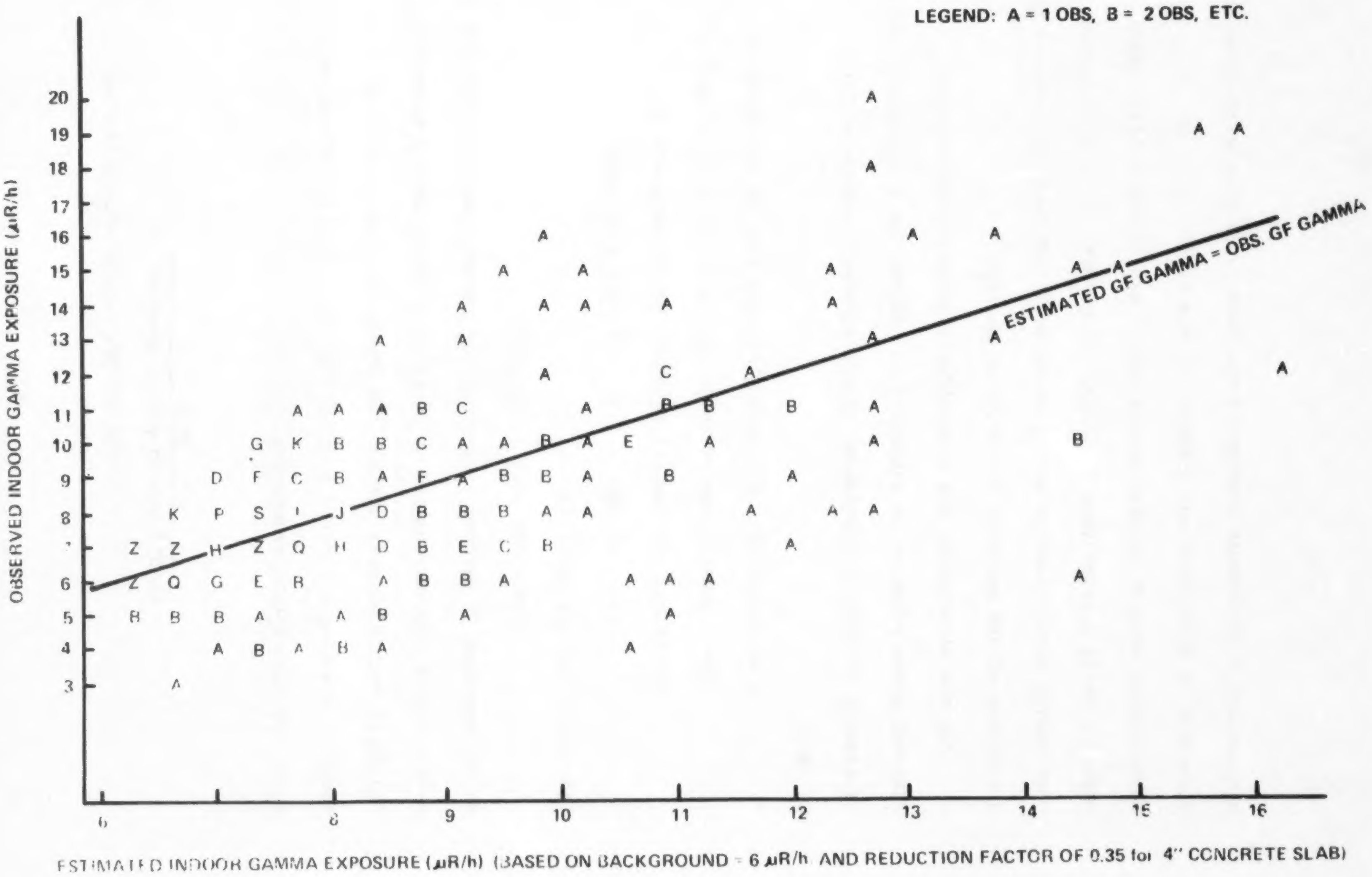
which, assuming 75 percent occupancy, 3.5 persons per structure and a mean lifetime exposure period of 70 years is equal to approximately 600 fatal health effects per 100,000 population (relative risk model). Assuming a control cost of $550 for a typical 4" concrete slab, the cost-effectiveness is:

$$\frac{\$550}{6\times10^{-3}\ \text{health effect averted}}$$

$$= \$28{,}000\ \text{per health effect averted}$$

Figure 10

CORRELATION OF OBSERVED INDOOR GAMMA EXPOSURE WITH THEORETICAL ESTIMATION



This calculation has been performed for several cases involving both new and existing structures. The results of these calculations are graphed in Figure 11 (a, b, c, d, e). The three levels of control for the cases described in Figure 11 (a, b, c) are successive 4" additional depths of concrete in the foundation, which is the least expensive control measure. Therefore, Level I (Fig. 11a) is the normal slab thickness of 4 inches, Level II (Fig. 11b) is a total of 8 inches, and Level III (Fig. 11c) is a total of 12 inches of ordinary concrete. The cost-effectiveness for controlling gamma exposure in existing structures (Fig. 11d) is based on excavation and filling with clean dirt in and around the structure's foundation, at a cost of $15,000 per structure as derived from the Grand Junction remedial program (Co78). A summary of cost-effectiveness for controlling indoor exposure in both planned and existing structures is provided in Figure 11e.

In controlling gamma exposure, some reduction in indoor radon decay products levels might also be achieved. However, because of the difficulty in reliably predicting such effects the cost-effectiveness estimates do not take them into account. While it is anticipated that radon decay product levels would generally be the primary factor in determining if radiation control is warranted, it would be prudent, particularly in new structures that require preventative measures and where acceptable radon decay product control can be achieved by a number of means, to consider measures which can minimize both

Figure 11a
COST-EFFECTIVENESS OF EXTERNAL GAMMA EXPOSURE CONTROL FOR PLANNED STRUCTURES (ASSUMING 4" CONCRETE SLAB CONSTRUCTION @ $550)

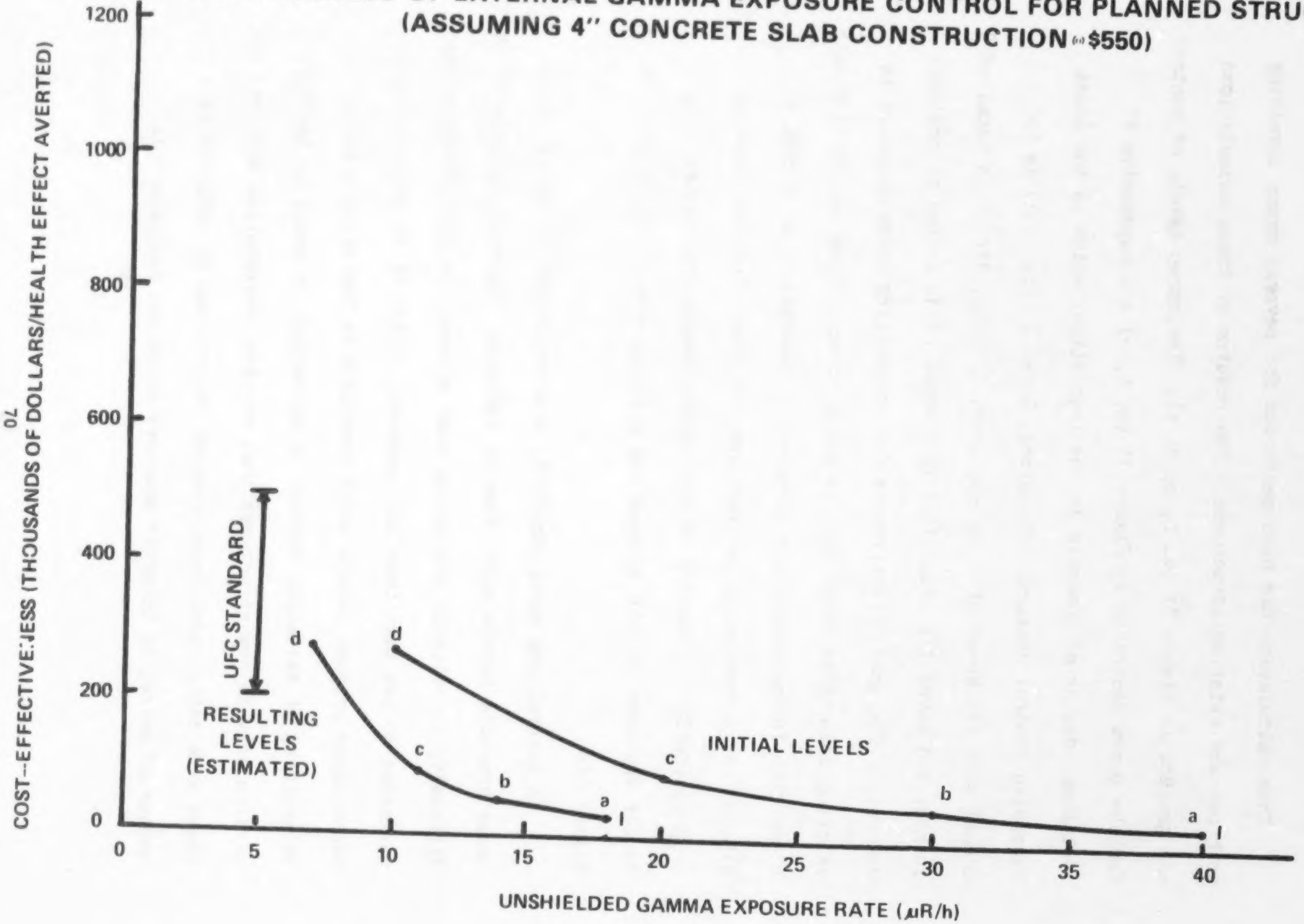


Figure 11b

COST-EFFECTIVENESS OF EXTERNAL GAMMA EXPOSURE CONTROL FOR PLANNED STRUCTURES (ASSUMING 8" CONCRETE SLAB CONSTRUCTION @ $1,500)

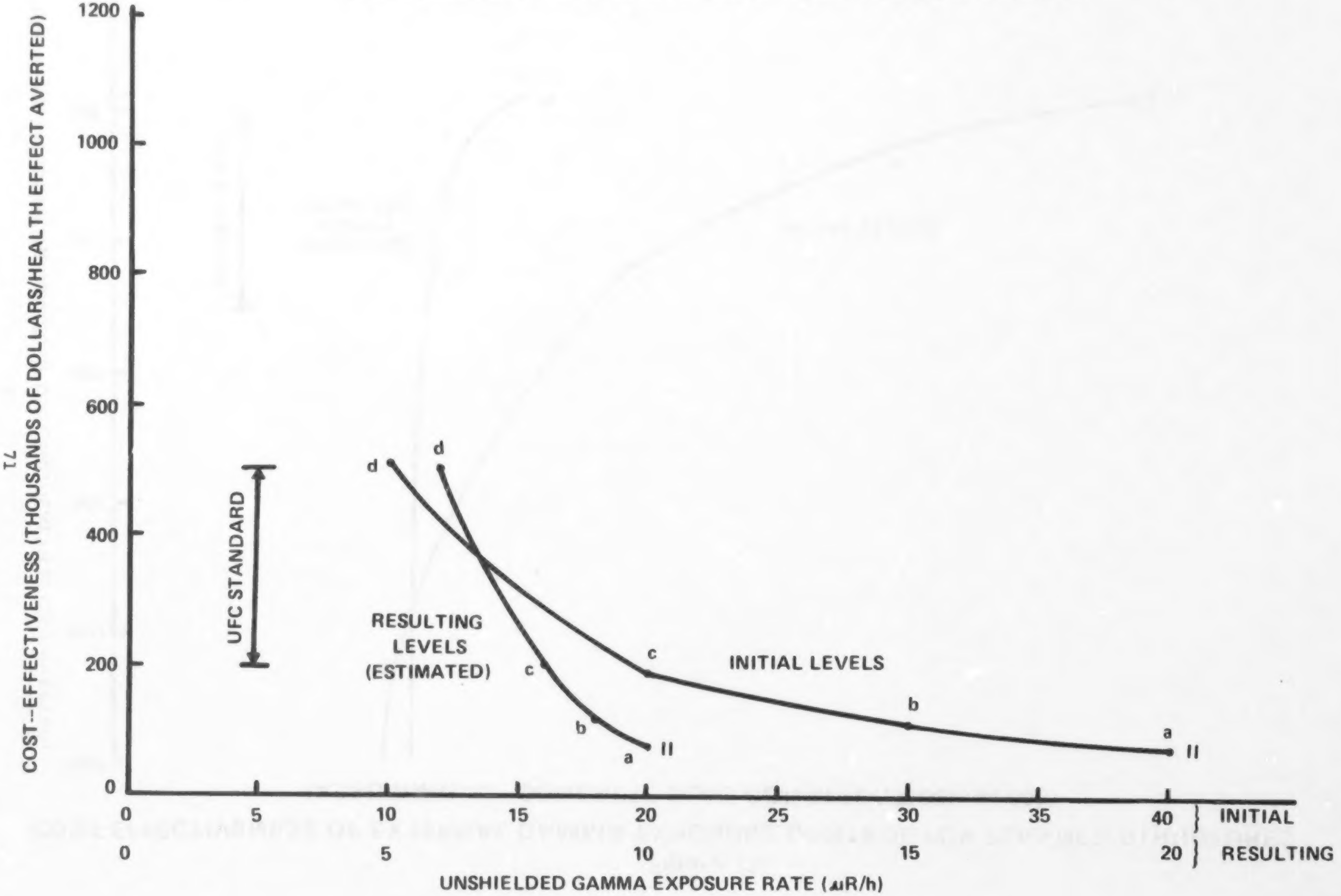


Figure 11c

COST-EFFECTIVENESS OF EXTERNAL GAMMA EXPOSURE CONTROL FOR PLANNED STRUCTURES

(ASSUMING 12" CONCRETE SLAB CONSTRUCTION@$4,000)

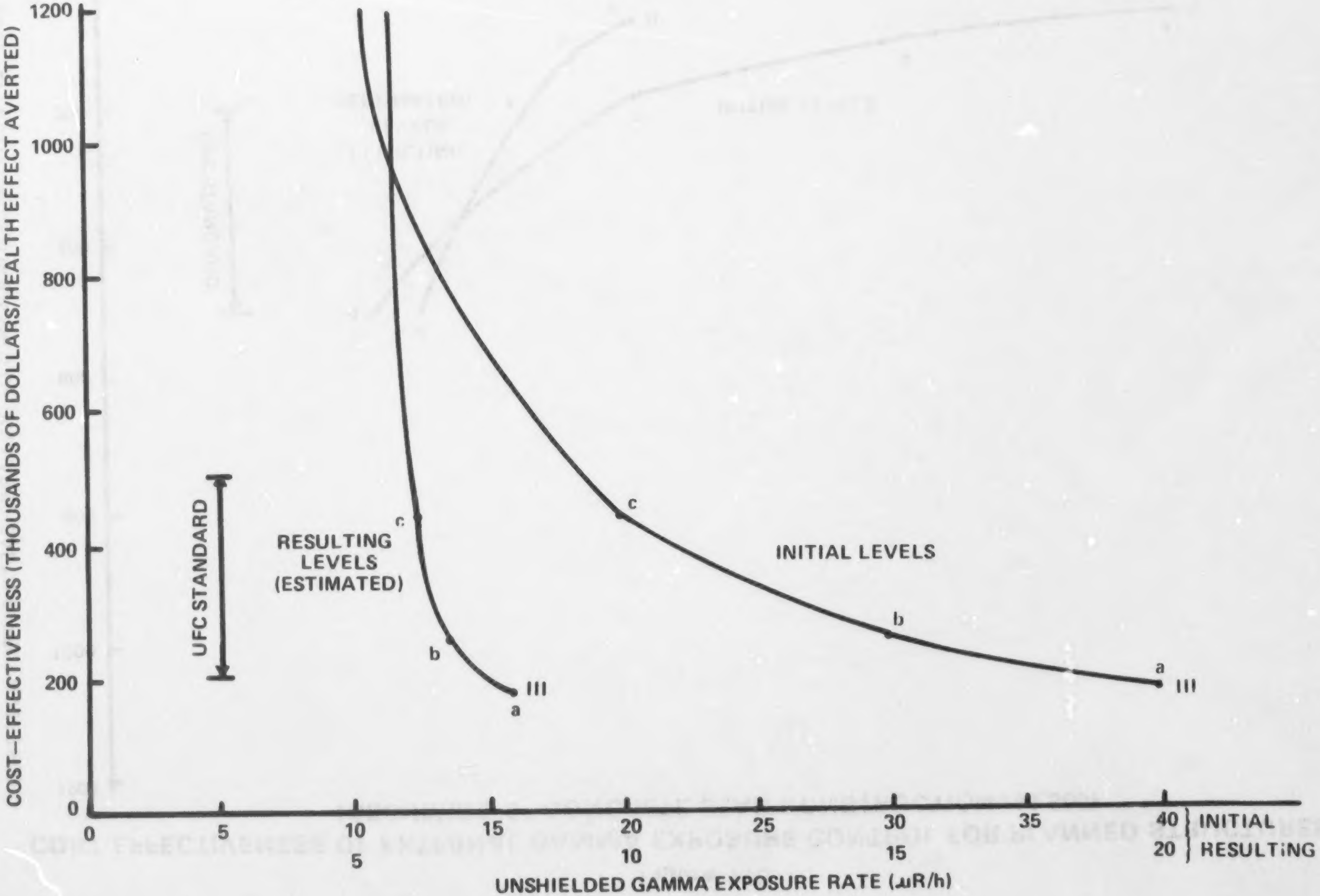


Figure 11d

COST-EFFECTIVENESS OF EXTERNAL GAMMA EXPOSURE CONTROL FOR EXISTING STRUCTURES (ASSUMING EXCAVATION AND FILL @ $15,000)

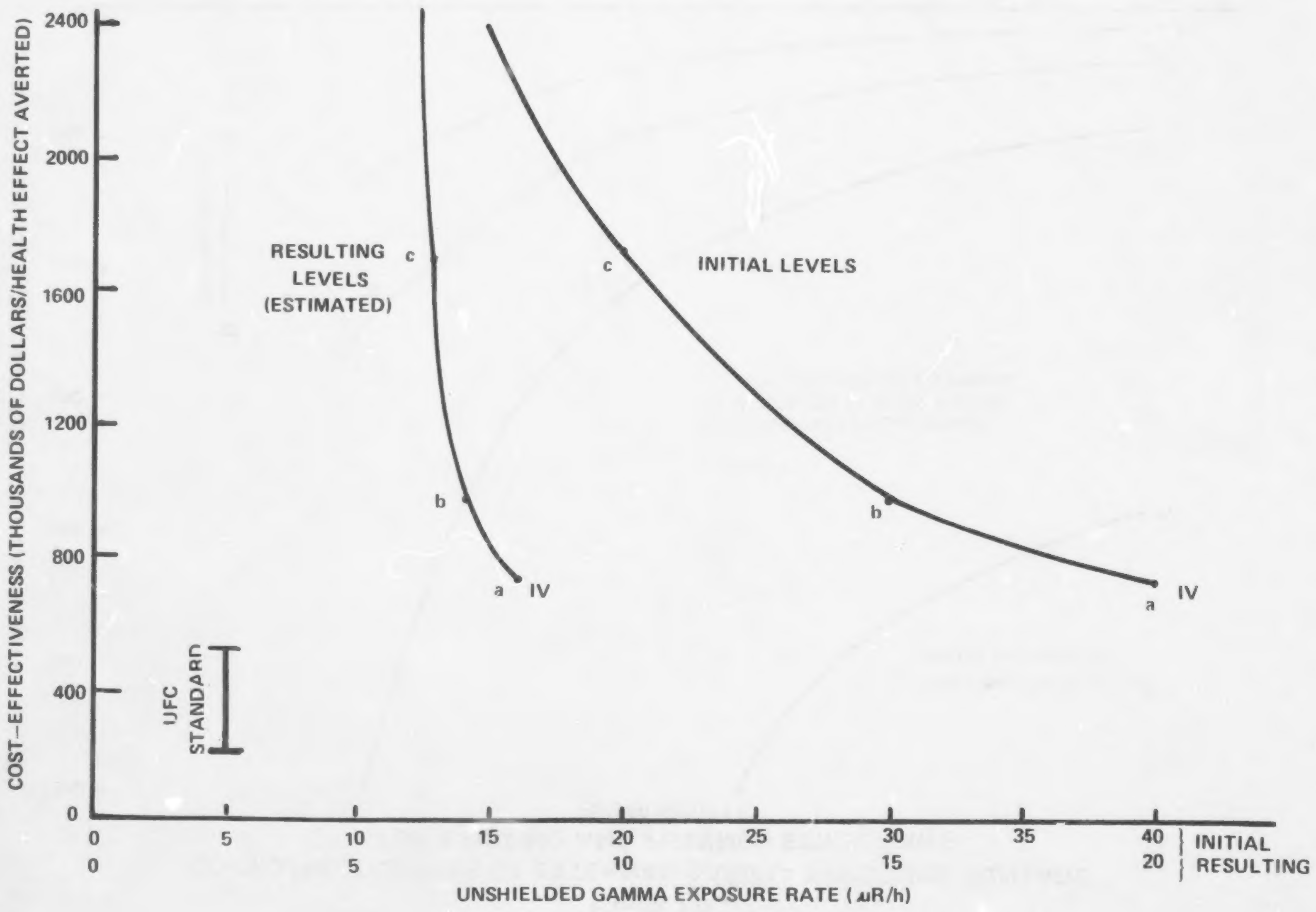
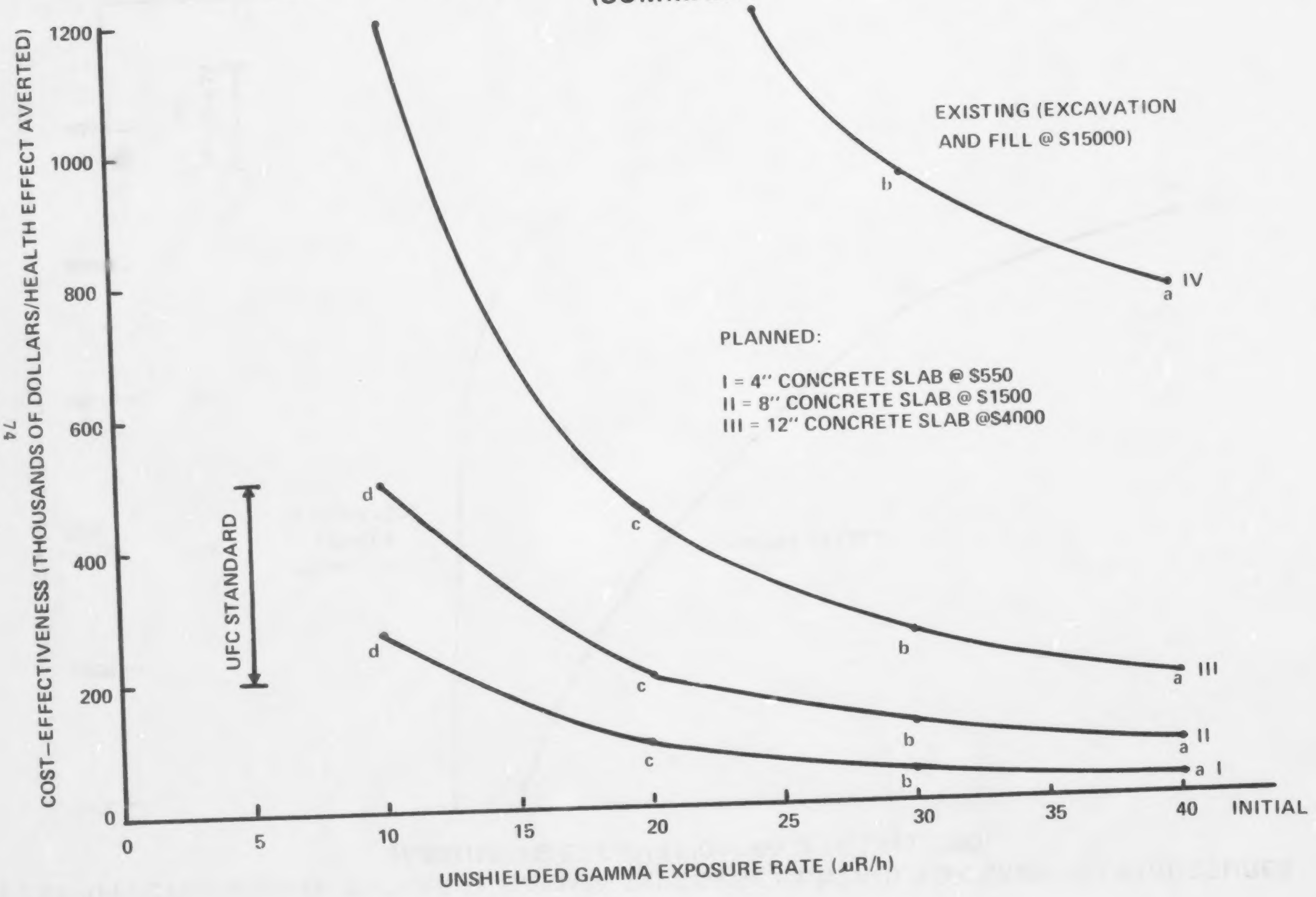


Figure 11e

COST-EFFECTIVENESS OF EXTERNAL GAMMA EXPOSURE CONTROL FOR EXISTING AND PLANNED STRUCTURES (SUMMARY)



radiation exposure components. An example is excavation and fill (for planned structures), which would remove both the source term for radon-222 diffusion and gamma radiation.

In conclusion, assuming that it is reasonable to spend about $200,000 to $500,000 to avert a health effect such as death or serious genetic damage (Un76), it appears from Table 12 and Figure 8 that it is cost-effective to apply most control technologies to reducing the indoor radon decay product levels in new and existing structures from levels at .005 WL above normal background (.009 WL gross) or higher. In some cases it may even be cost-effective to apply radon control technology at indoor radon decay product levels less than .005 WL above normal background. However, this depends greatly on specific sites and structures and a case-by-case review is required at such levels.

In examining cost-effectiveness for control of gamma exposure, review of Figure 11 suggests that in new structures, Control Level I is cost-effective for initial gamma exposure rates greater than 4 μR/h above normal (10 μR/hr gross), Control Level II is cost-effective for rates greater than 14 μR/h above normal (20 μR/h gross), and Control Level III is cost-effective at rates greater than 24 μR/h (30 μR/h gross). For existing structures, review of Figure 11 indicates that it does not appear to be cost-effective to retrofit structures with control measures solely to reduce external gamma radiation exposure.

SECTION 6.0

ALTERNATIVES FOR RADIATION PROTECTION

6.1 EXISTING RADIATION PROTECTION GUIDANCE

At present there are no Federal radiation protection guidelines specific to radon daughter levels in structures. Recommendations of the former Federal Radiation Council* published in 1960 established annual guides for exposure of the whole body of 500 mrems to an individual in the general population and 170 mrems to an average member of critical population groups. The Council further noted that "every reasonable effort should be made to keep exposures as far below this level as practicable." However, these limits excluded natural background radiation, and it is not clear whether or not they were intended for application to situations in which man has artificially increased this natural background.

Another potentially relevant Federal guide is the U.S. Surgeon General's Guidelines for remedial action in Grand Junction, Colorado (Pe70). These guidelines, given below, were developed in 1970, for use in establishing remedial action criteria for structures having uranium mill tailings under or around them.

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*When the Environmental Protection Agency was established by Reorganization Plan No. 3 in 1970, the functions and authority of the Federal Radiation Council were vested in EPA.

SURGEON GENERAL'S GUIDELINES:

RECOMMENDATIONS OF ACTION FOR RADIATION EXPOSURE LEVELS IN DWELLINGS CONSTRUCTED ON OR WITH URANIUM MILL TAILINGS

External Gamma Radiation

Level	Recommendations
Greater than 0.1 mR/hr	Remedial action indicated
From 0.05 to 0.1 mR/hr	Remedial action may be suggested
Less than 0.05 mR/hr	No action indicated

Indoor Radon Daughter Products

Level	Recommendations
Greater than 0.05 WL	Remedial action indicated
From 0.01 to 0.05 WL	Remedial action may be suggested
Less than 0.01 WL	No action indicated

The Surgeon General's Guidelines apply specifically to dwellings constructed with or on uranium mill tailings, and as noted when they were issued, should not be interpreted as being applicable to other cases. Since these guidelines were developed, additional information has become available regarding the risk associated with exposure to radon decay products.

6.2 BASIC RADIATION PROTECTION PRINCIPLES

For the purpose of developing radiation protection recommendations for acceptable indoor radiation levels of radon decay products, the most realistic basis for health risk estimates is epidemiological studies of groups previously exposed to elevated levels of radon decay products. A linear nonthreshold dose-effect relationship has been assumed to be a prudent model for deriving risk estimates for the general public from these data, in the absence of contrary information. This assumption implies that there is some risk to humans no matter how small the amount of absorbed radiation and that the risk at low dose levels is directly proportional to that observed at higher doses. In judging the acceptability of such risks, it must be considered that all persons are exposed to a large number of competing risks, including other radiation risks, and any reduction of risk from a single source must be viewed in the overall perspective of the social and economic impacts involved. The assumption that any exposure to low level ionizing radiation has some degree of associated adverse health effects is reflected in guidance issued by the Federal Radiation Council (FRC) in 1960 (Fe60) that any necessary exposure should be reduced to "as low as practical" (ALAP) levels. This guidance also recommends that any planned exposure above zero (or background) be justified on the basis of a benefit which, as a minimum, balances the risks associated with the exposure. Since the benefits of residence in a particular location or in a specific structure cannot be quantified on a generic basis (if, indeed, they can be assessed at all) this latter guidence is not addressed here. The ALAP criterion was addressed on the basis of an examination of the cost-effectiveness of control, in terms of dollars per health effect averted.

6.3 ALTERNATIVES FOR RADIATION PROTECTION

A number of alternatives are available, both for the form of radiation protection recommendations and alternative levels of control. Consideration of administrative alternatives (as opposed to alternative criteria levels), e.g., no action or delayed action, however, are not addressed as they are not within the scope of this discussion. It should be emphasized that the control levels discussed in this section are provided as examples and do not reflect all of the options possible.

Three basic alternatives bearing on the level and degree of control may be considered. In summary, these are:

1. Define a nationally applicable level of unacceptable continuous radon daughter exposure based on consideration of the acceptability of the health risk, with remedial measures also taken below this level, whenever reasonable, based upon local determinations.

2. Define an upper control limit for structures built on phosphate land in Florida based upon two considerations: 1) the improvement judged reasonably achievable using remedial measures for the majority of cases in Florida, and 2) a judgment of the unacceptability of the health risk above this level. Define a lower limit based upon practical limitations of uncertainty in background, and the effectiveness of remedial measures, below which no consideration of remedial action is recommended. Between these limits, the implementing authorities would be advised to assess the practicability of specific remedial measures on a case-by-case basis.

3. Define a lower limit only, below which consideration of remedial action is not recommended. Above this level, remedial action, justifiable on the basis of available cost-effectiveness information, would be taken. The degree of control warranted would be determined on a case by case basis taking into account such factors as cost and effectiveness of available remedial measures, the lifetime risk averted, the normal background level, the life expectancy of the structure, and measurement uncertainties.

The principal obstacle to establishing a national recommendation (first alternative) is limited knowledge of national radon levels. This makes it difficult to predict, on either an absolute or relative basis, what levels can be achieved reasonably or the scope of the public health problem. In addition to variation in air leakage rates of structures with climate (this variable can have a profound effect on radon levels), new potential radon problems are still surfacing. The phosphate situation, itself, was only recently uncovered. Within the last year, newly identified comparable situations have been identified arising from thoron, an analogue of radon from thorium deposits present in monazite sands in Georgia and to a small degree, in parts of Florida. The magnitude of the potential health risk associated with chronic exposure to radon decay products at levels observed on phosphate lands in Florida appears to justify action independent of consideration of guidance development on a national level.

Alternative 2 contemplates a lower bound for consideration of remedial action which would reflect practical limitations on measurement and the effectiveness of remedial action and an upper level above which remedial action would be mandatory. This lower bound to ALARA lies approximately at the 0.005 WL (above background) level, on the basis of experience with such measurements and cost-effectiveness of available remedial measures developed in this study (see Figure 8). The major advantage of this option is its underlying recognition that, given the limitations of technical information currently available on radon levels in residences, costs of remedial action, and the efficacy of remedial measures, it is desirable to define a reasonable range of flexibility within which local authorities can address these uncertainties. This flexibility may also be of importance to individual homeowners who, after consideration of the reasonableness of reducing their risk, may decide to take more or less action than called for by strict cost-effectiveness considerations alone, due to personally overriding considerations such as their age, the remaining period of usefulness of the structure, and their ability to pay for the incorporation of control measures.

An upper bound criterion level above which remedial action would be mandatory should be based on a balancing of health risk considerations and the estimated reasonableness of the costs of control action to bring indoor radon decay product concentration in the worse cases down to at least this level. As a function of the level selected, there may be a significant fraction of structures which will not be remediable to a sufficient degree to satisfy such a level. For these particular structures, the options would be few, consisting probably of either forced abandonment or the application of non-cost-effective remedial action. This inherent disadvantage of a mandatory criterion, can be minimized if the level chosen can be projected to be attainable at reasonable cost in all or nearly all cases.

The overall shortcomings of this alternative, like the advantages, are inherent in the implementation of ALARA. Because its implementation within the specified range would be left to the discretion of local authorities or the homeowner, there is the possibility that ALARA will be implemented incorrectly or not at all. While education on the subject and government advice might reduce the instances of misuse, the only means to assure implementation would be to remove the flexibility provided by two levels. It is also possible to recommend that remedial action be mandatory within this range with the degree of control to be applied at the local authorities or the homeowner's discretion. Despite public education and assistance in making determinations as to the level of control at which ALARA is satisfied for individual cases, implementation could still be highly variable, depending on factors such as the individual's ability to afford control measures, their ability to comprehend the risk and the "cost-effectiveness" of control involved, and the extent to which assistance is available from local authorities.

Alternative 3 is an option under which the implementation of remedial action would be called for at all indoor radon decay product levels, above a minimum level, whenever reduction is reasonably achievable. All of the difficulties present in the range between the two levels provided by Alterntive 2 would apply to the whole range of levels that fall above the single level provided in this Alternative. In many situations observed in Florida it would be desirable and practical to reduce the chronic exposure to radon decay product levels to considerably less than an upper bound criterion level, as provided for by Alternative 2. Review of the control technology and cost information indicates that in many circumstances it is not unreasonable to achieve a post-control indoor radon decay product level of less than 0.005 WL above normal background (0.009 WL gross). However, at indoor radon decay product levels less than 0.009 WL (gross) it becomes increasingly difficult to accurately measure and differentiate the observed level from normal background. Other sources of radon other than those amenable to control by the available technologies may significantly contribute to the observed indoor radon decay product air concentrations. These factors tend to increase the implementation problems for local agencies at and near the 0.005 WL above background level.

6.4 SELECTION OF RADIATION PROTECTION LEVELS

In developing radiation protection guidance, the following objectives are important in selecting appropriate action levels:

1. Minimize the health risk to the affected population.

2. Determine that recommended radiation levels can be measured with reasonable accuracy, and, when necessary, differentiated from normal background.

3. Determine that suitable control measures exist to reduce indoor radiation levels to the recommended levels.

4. Determine that application of control measures does not require the expenditure of unreasonable resources by individuals, government authoritities or other groups.

5. Determine that the recommendations can be understood and practically implemented by State and local responsible authorities, and by the general public.

These objectives call for a series of judgments on the part of the Agency in its guidance role, and the State or County in their role as implementing authorities.

6.4.1 Radon Decay Product Levels in Existing Structures

As shown in Figure 8, some control of indoor radon decay product levels in existing structures can be considered cost-effective at all initial levels greater than 0.01 to 0.02 WL (including background). This assumes control costs of $900 - $2600 per structure and 80 percent reduction. However, if the initial level is sufficiently high, remedial action at these cost levels and at 80 percent reduction efficiency may not be sufficient to bring a structure down to the

0.01-0.02 WL range. Therefore, the selection of an action level equal to or above this lower bound is also dependent more on practical considerations of the degree of reduction economically achievable. As illustrated in Table 13, the most basic factor bearing on economically feasible implementation is the proportion of structures which require application of nonconventional control measures (i.e., other than those listed in Table 12), in order to be brought into compliance with the numerical criterion selected. At successively lower action levels, the fraction of structures not easily remediable increases. At 0.01 WL, for example, 15 percent of structures located on phosphate land are projected to require more than readily achievable reduction in levels compared to none expected at .03 WL, as extrapolated from the EPA/DHRS survey. Using the .03 WL value as a baseline (i.e., assuming that no unusual costs are projected at this level), additional costs of \$260,000 - \$640,000, and \$2,600,000 - \$6,400,000 would be accrued,respectively, at 0.02 WL or 0.01 WL (assuming that 1/3 of structures not conventionally remediable require special corrective action at a cost of \$10,000 - \$25,000 per structure). The cost-effectiveness of applying these "special" measures is generally in excess of hundreds of thousands of dollars per health effect averted. This obvious disparity between the cost-effectiveness of conventional measures compared to unconventional ones is a result of the latter's high cost coupled with the relatively small additional reduction achievable.

TABLE 13

IMPACT OF ALTERNATIVE CRITERIA FOR INDOOR RADON DECAY PRODUCT EXPOSURE FOR STRUCTURES REQUIRING SPECIAL CORRECTIVE ACTION

(1)	(2) Number and Percent of Structures in Excess			(3) Number and Percent of Structures not Conventionally Remedial*			(4)	(5)
Recommended Remedial Action Level (RRAL)	(A) EPA/DHRS Survey (N=104)	(B) Extrapolated (N=4000)	(C) Percent	(A) EPA/DHRS Survey (N=104)	(B) Extrapolated (N=4000)	(C) Percent	Extrapolated Total Cost of Special Corrective Action for Structures not Conventionally Remedial** (N=4000)	Cost-effectiveness of Special Corrective Actions (dollars per health effect averted)***
.03 WL	20	760	19	-	-	-	-	-
.025 WL	23	880	22	1	40	1	$130K - $320K	$140K - $430K
.02 WL	25	960	24	2	80	2	$260K - $640K	$170K - $560K
.015 WL	30	1160	29	7	270	7	$900K - $2,200K	$220K - $810K
.01 WL	45	1720	43	20	770	19	$2,600K - $6,400K	$330K - $1,500K

*Assuming 80 percent efficiency of control measures in reducing indoor radon decay product levels which exceed background.

**Assuming 1/3 of structures not conventionally remediable require special corrective action, at a cost of $10,000-$25,000 per structure.

***Assuming the above efficiency and costs for reduction from this and the previous RRAL for a structure housing 3.5 people.

The development of appropriate action level, therefore, requires judgment as to the most acceptable balancing of overall cost-effectiveness with practical considerations, such as achievability of control levels and measurement error. Given the aforementioned cost of applying unconventional remedial measures and the problems associated with measurement error at the lower levels, it appears unreasonable to recommend mandatory action at levels less than 0.02 WL. Within the 0.02 to 0.03 range (the latter again representing a level projected to be reasonably achievable in all structures), the acceptability of a projected less than one percent of existing structures requiring non-cost-effective remedial action must be based on a judgment on the appropriate allocation of resources to achieve reductions in health hazard, and the capability and willingness of responsible parties to provide assistance programs for those structures requiring additional corrective action.

6.4.2 Radon Decay Product Levels in Planned Structures

Reduction of indoor radon decay product levels is more practical in new than in existing structures as shown in Figure 8. This is because structure design, site preparation, selection of construction materials, and the location can be planned. Through careful consideration of these factors, almost all structures can and should be designed to achieve ALARA, or 0.005 WL above background, as determined for construction on phosphate land in Florida. It is possible that in some cases following construction using what was anticipated to be properly designed control measures, the indoor radon decay product level will be greater than 0.005 WL above normal. In some of these cases additional controls may be warranted but in others the lowest practical level may already be achieved. Such a determination will require a case-by-case review. The cost-effectiveness of these additional controls would, of course, be the same as that for existing structures as shown in Figure 8.

6.4.3 Gamma Exposure in Existing Structures

The highest indoor gamma radiation dose observed in the examination of 1102 residential structures in Florida was 190 mrem/yr (27 μrem/hr assuming 75 percent occupancy). It is not expected that a significant number of structures with indoor radiation levels much above or equal to this value will be identified. As shown in Figures 11d and e, the apparent cost of reducing this exposure is high and it appears unreasonable to attempt reduction of such gamma levels in existing structures.

6.4.4. Gamma Exposure in New Structures

As is the case for radon, the availability and cost-effectiveness of control measures for gamma radiation exposure (as shown in Figures 11a-11e and discussed in the preceding section) in residences is such that in most situations anticipated in Florida on phosphate lands, it is reasonable to design and site a new residence so that the indoor gamma radiation exposure rate in the completed structure is less than 5 μR/h above normal gamma radiation background (normal is approximately 6 μR/hr). Assuming 75 percent occupancy, exposure at this rate(11 μR/h) is estimated to result in about 100 additional cancer fatalities annually per 100,000 persons exposed over a lifetime. Designing structures to achieve an indoor gamma exposure rate less than about 10 μR/hr (gross) is impractical, since differentiating between normal background and elevated levels becomes increasingly difficult below 10 μR/hr. Also, as in the case for radon daughters, other sources of radioactivity such as construction materials, may be significant contributors to the overall gamma exposure at these levels. Because of high retrofitting cost, once a structure is built using a design and siting plan to minimize indoor gamma radiation exposure, no additional control is warranted for gamma reduction even if the recommended gamma ray exposure guide is exceeded.

SECTION 7.0

SOCIO-ECONOMIC IMPACT

7.1 GENERAL CONSIDERATIONS

At present, the socio-economic impact of implementing remedial measures can only be evaluated on a qualitative basis, with emphasis on the identification of probable areas of impact. The actual number of residences affected, the field effectiveness of control measures and their specific costs, as well as the availability of financial aid, are among the factors not totally known at this time. Additional information in each of these areas may have a substantial effect on socio-economic impact.

The region under consideration includes about 300,000 acres of land in central and northern Florida. Three general areas are covered by the following discussion: impact on public and private institutions and services, impact on business and employment patterns, and personal impact.

7.1.1 Impact on Public and Private Institutions and Services

Evaluation of potential impacts in this area includes modifications in the availability of housing in the region as a result of radiation protection measures, and the added burden on local health and building inspection departments. Among the primary forces that would affect availability and property values negatively are the reluctance of developers and private builders to use phosphate land, and possibly, the higher selling price (to cover the additional cost) and/or poor market for houses that have had remedial action. The magnitude of these factors depends upon the availability of alternative construction sites, the ingenuity of construction firms in incorporating remedial measures into housing plans, and the attitude of potential home purchasers toward houses with remedial measures. These factors would, in turn, rely on the type of remedial measure implemented, its cost, and the degree of assurance for the builder or homeowner that radiation levels will be effectively reduced.

The effect of the additional workload on local government from implementing necessary radiation protection measures could be significant, at least initially. There will be a need for additional inspections, surveying and recordkeeping, as well as laboratory facilities for radiological analyses. The availibility of the necessary additional resources will be dependent on the financial resources of the individual local health and housing departments. In some cases either local programs may require cutbacks or the recommendations may not be implemented fully. To estimate the total potential economic impact on industry and the housing market quantitatively would be totally speculative at this time. At a cost of about $50-100 to determine radiation levels in one structure, the evaluation of the 4000 structures estimated to be in the region would cost about $200,000-$400,000. Clearly, these values could vary depending upon the present capabilities of the local agencies.

7.1.2 Impact on Business and Employment Patterns

With respect to the local economy, an equilibrium will result between the positive and negative aspects of implementing a remedial action program. The positive aspect would primarily be the economic advantages to business dealing with products or services called for in the remedial action program. The negative aspect would be the detrimental effort such implementation could have on businesses dealing with housing construction or land development. The net effect for the area in question would be dependent upon a number of variables, the most important of which is likely to be the impact of reduced home construction and/or sales, whatever the reason (e.g., public attitude). For a high growth area such as Central Florida this would be of some consequence if realized, although the low cost of control measures for new residences should make a significant impact on construction firms from this cause a remote possibility.

7.1.3 Personal Impacts

Some degree of personal impact is likely for those persons residing in structures which have been found to be in need of remedial action. Depending upon the type of measure implemented, some degree of disruption to the occupants' lives, either through the initial incorporation of a passive remedial measure, or the periodic maintenance required for one of a non-passive nature, may result. The cost of the remedial action, if necessary, may also have to be assumed fully or in part by the homeowner, thereby posing a significant economic burden. However, this negative impact may be merely one segment of the overall cost to the homeowner, since the presence of any remedial measures (other than the truly passive ones such as crawl spaces) may affect the saleability of the residence and its market value. Other determining factors would be the status of the housing market in the area and attitudes of buyers towards the radiation problem and remedial action.

7.2 MAGNITUDE OF THE AREA POTENTIALLY AFFECTED

About 120,000 acres of land have been mined for phosphate rock in Florida; of that amount, about 50,000 acres have been reclaimed to various degrees. Estimates suggest that approximately 7,500 acres are being used for residential housing or commercial purposes, with about 1,500-4,000 structures. The total acreage which contains elevated radium-226 concentrations near the surface, but is unmined, is unknown at present, but preliminary research indicates that it may be quite significant.

Land underlain by phosphate ore is located in the Central Florida counties of Hillsborough, Polk, Manatee, Hardee, Highlands, Desota, and Sarasota as well as several Northern Florida counties. Based upon field experience, we do not believe that all of the land where phosphate ore is located or all of the disturbed phosphate mine lands will pose indoor radiation exposure problems to residents of structures built there. Nonetheless, because of the radium-226 content of phosphate materials, the potential for indoor radon daughter problems must be anticipated and adequately evaluated wherever the phosphate materials and associated radium-226 are present. It is important to note that radium-226 associated with other minerals in Florida, such as rare earths, titanium, and monazite sands, may pose similar risks to residents.

7.3 ECONOMIC IMPACT OF REMEDIAL ACTION

Characterization of the economic impact of implementing remedial measures for both existing and planned structures is performed by consideration of the cost range of probable implementation scenarios. Consideration is specifically limited to remedial costs as listed in Table 12, although it is recognized that impacts as described in the preceding section would also be applicable. As estimated in the DHRS Final Report (1978), there are approximately 4000 structures built on phosphate reclaimed land in Polk and Hillsborough Counties. Statistics are not readily available on the number of new structures being built or considered for reclaimed phosphate land. However, a rough estimate can be made on the basis of annual housing starts for those cities and towns located in the vicinity of identified areas of reclamation. From data published by the Bureau of the Census (1977), approximately 400 housing starts are noted for incorporated municipalities located in such areas of Polk and Hillsborough Counties for 1976. There were 3012 housing starts in unincorporated areas of both counties in 1976. Approximately 50 in Hillsborough County and 950 in Polk County are assumed to be located in the phosphate area as defined in information derived from the respective county building permit offices. Of the 1400 total housing starts, as many as 40 percent may need control measures to meet the recommended design objectives, based on an analysis of the distribution of existing structures. Therefore about 500 structures, or about 15 percent of new residential construction starts in the two counties, are projected to require remedial consideration per year.

From the combined (EPA and DHRS) TLD air sampling data collected and the application of the findings made in Section 6, the remedial cost range for the 4000 existing structures can be projected. With .02 (including background) WL as an upper control level, approximately 24 percent of the total sample, or 960 structures out of the estimated 4000 structures, is projected to be in excess. In addition, one third of 2 percent of structures may require special corrective action to meet this control level at a cost of $270,000 - $670,000. At a lower control level of 0.009 WL (0.005 WL + 0.004 WL background), approximately 40 percent of existing structures or a total of 1600 structures on reclaimed land would exceed this criterion. Assuming an average remedial cost per structure of approximately $1,000, as derived from Table 12 (assuming application of polymeric sealants), a cost of one to one and a half million dollars is projected for this range of control levels. Selection of an appropriate measure and cost for existing structures is difficult due to lack of data, but, generally, the individual cost of the various available control measures is similar and this figure ($1000) is representative of any of them. With more limiting mandatory action levels (e.g., 0.01 or 0.02 WL), the total cost projected would be higher commensurate with the number of structures requiring additional or special corrective action to satisfy the recommended control level. With a mandatory control level of 0.01 WL, and assuming that all not conventionally remediable structures identified in Table 13 require special corrective action, rather than only one third, and, further, assuming a cost for such special corrective action of $25,000 per structure, the maximum total cost would be $17,000,000.

Estimates for future structures to be built on reclaimed land assume 500 construction starts per year over a ten year period, with the cost of control over this period of time being $500 per structure for a total of about $2,500,000. The economic impact due to remedial action in both counties for such a ten year period would be about three to four million dollars (undiscounted 1977 dollars). This estimate is clearly a function of the rate of new house construction on reclaimed land, which in turn depends on many variables, including the growth rate of the counties, availability of reclaimed land, zoning requirements, etc. Due to the relatively low cost associated with crawl space implementation, however, this cost estimate is probably a low one, assuming that other types of structure would also be built.

SECTION 8.0

IMPLEMENTATION OF RADIATION PROTECTION MEASURES

8.1 FEDERAL ROLE

These findings were developed through the Agency's authority to provide technical assistance to States. The U.S. Environmental Protection Agency has no authority to directly enforce recommendations in the State of Florida. However, under authority transferred to the Agency in 1970, EPA can develop Federal guidance for protection of people exposed to radiation sources associated with structures. Such guidance would apply to Federal agencies in the conduct of their regulatory and other programs.

8.2 STATE AND LOCAL ROLE

In order to implement radiation protection measures effectively, it will be necessary for State and local agencies within Florida to enforce and carry them out. To this end, appropriate State and local agencies could adopt measures such as those discussed in this document through their own regulations which could be in the form of zoning requirements, building codes, standards, or some other suitable mechanism. In some cases, in order to provide effective implementation, additional State and/or local authority may be necessary.

8.3 CONDUCT OF STRUCTURE EVALUATIONS

In carrying out remedial action, State and local governments, as well as private individuals or groups, will need to conduct a variety of measurements and evaluations to make appropriate decision-making possible. To assist uniform application of any recommendations, the Agency has developed suggested measurement guides for assessing radiation levels in existing structures. Information on indoor radon decay product exposure is necessary to determine whether remedial action is warranted. In planning new structures, data on gamma radiation exposure is necessary. All radiation measurements should be performed by trained technicians using properly calibrated radiation detection equipment.

Indoor radon decay product air concentration measurements should be made using a Radon Progeny Integrating Sampling Unit (RPISU) or some other appropriate system. If the RPISU or similar device is used, the average indoor radon decay product level for a test structure should be the mean of four to six measurements made over a one-year period. Single measurements totalling less than 24 hours integrating time or multiple measurements of less than 125 hours should not be used in determining the average indoor radon decay product level unless absolutely necessary. Devices such as instantaneous working level meters, grab radon or radon daughter product samples, and track-etch films may be helpful in screening numerous structures to determine those most likely to exhibit elevated indoor radon daughter levels. However, they should generally not be used for remedial action decision-making unless the data is shown to be of quality comparable to that obtained with the RPISU device. We anticipate that work by the Agency or other groups may be able to improve the decision-making usefulness of short-term measurements in the future.

8.4 CONTROL COST-EFFECTIVENESS ASSESSMENT

Current Federal guidance for radiation protection provides for reduction of exposures to as low as reasonably achievable (ALARA). It is recognized that such guidance requires decisions at the local level regarding which exposure level can be considered ALARA. This value will differ from case to case and there are several factors to be considered. First, the reliability of the data should be appraised. How much measurement error is involved? Second, the normal background level, which is conventionally the initial baseline for ALARA, should be considered. Third, the cost to achieve the desired exposure reduction should be evaluated. This factor is extremely important. If the cost is minimal, then nearly any reduction (to normal background) would be desirable. However, if the cost is substantial, then the associated potential decrease in risk must be weighed by the homeowner or the local authorities to determine if the application of control technology is warranted. Fourth, the potential impact of the dwelling on future inhabitants must be considered. If the structure is very old and in poor condition and is unlikely to be inhabited to any significant degree in the future, it will have less long-term impact on public health. Fifth, the social inconvenience and other impacts on the inhabitants may be considered. The installation of control technology may cause a significant disruption to the normal lifestyle and adverse impact on the well-being of the inhabitants. Sixth, the economic situation of the inhabitants should be evaluated. Some residents may be unable to afford to install control technology due to adverse economic circumstances.

These factors are not listed in order of importance since they clearly vary from situation to situation, nor do they represent all factors that may need to be considered. However, it must be emphasized that the decision on whether remedial action is warranted at any level should be based upon an overall evaluation of what is cost-effective and practicable for present and future occupants.

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GLOSSARY

Activity - The number of nuclear transformations occurring in a given quantity of material per unit time. The curie is the special unit of activity. One curie equals 3.7 x 10^{10} nuclear transformations per second (abbreviated Ci).

Apatite -Any of a group of calcium phosphate minerals of the approximate general formula Ca (F, Cl OH,1/2 CO) (PO) occurring variously as hexagonal crystals and granular masses; or in fine-grained masses as the chief constituent of phosphate rock and of bones and teeth, specifically calcium phosphate fluoride CaF(PO).

Beneficiation- The processing of ores for the purpose of (1) regulating the size of a desired product, (2) removing unwanted constituents, (3)improving the quality, purity or assay grade of a desired product.

Decay product- A nuclide resulting from the radioactive disintegration of a radionuclide, formed either directly or as the result of successive transformations in a radioactive series. A decay product may be radioactive or stable (also known as a daughter).

Gamma Radiation- Short wavelength electromagnetic radiation of nuclear origin (range of energy from 10 KeV to 9 MeV) emitted from the nucleus.

Latent Period - The period or state of seeming inactivity between the time of exposure of tissue to an injurious agent and response.

Matrix - The subsurface of material containing a mineral or metallic ore.

Pressurized ion chamber - A pressurized gas-filled chamber used for the detection of ionizing radiation. The increased pressure enhances its ability to monitor low-level gamma radiation (1-200 R/hr).

Radon - A heavy radioactive (alpha and gamma) gaseous element of the group of inert gases formed by disintegration of radium.

Radiogenic - Produced by radioactivity.

Relaxation length - An absorber thickness which reduces the intensity of the radiation by a factor of 1/e.

Scintillation instrument - A device for detecting and registering individual scintillations (flashes) of light produced in a phosphor by an ionizing event as in radioactive emissions.

TLD air pump - A device used to measure radon daughter levels utilizing techniques of thermoluminscent dosimetry.

Track-etch film - A device used to measure radon daughter levels utilizing a 1/2" x 1" plastic chip which is coated with cellulose nitrate. The alpha particles (produced by radon daughters) react with the cellulose nitrate, thus leaving a record.

μR/hr - Microroentgen per hour (1 x 10 roentgen per hour). Unit used for gamma radiation levels.

WL (Working Level) - The potential alpha energy from short-lived daughters of radon which will produce 1.3 x 10^5 MeV in one liter of air.

APPENDIX A

STUDY DESIGN - TECHNIQUES AND PROCEDURES

I. PILOT STUDY DESIGN

In June 1975, a limited field study was initiated to determine whether the elevated concentration of radium-226 in reclaimed phosphate land has an impact on increasing the radon decay product levels in structures built on the land. A sample was selected of Polk County structures built on reclaimed and non-reclaimed land. Except for that variable (i.e., reclaimed versus nonreclaimed), structures were selected as randomly as practicable. The overall sample size was 125 structures, with two-thirds of them being reclaimed land sites. The remainder were nonreclaimed land sites, some in the phosphate district. This limited study was not intended to evaluate radon decay product levels in all structures throughout the County, but rather to give a perspective on the possible problems and thereby point the way to further evaluation, if needed.

II. GAMMA EXPOSURE INSTRUMENTATION

Gamma radiation levels inside and outside structures were determined with Ludlum Model 125 Micro R meters that were calibrated with a Reuter-Stokes Pressurized Ion Chamber relative to a slab source (phosphate materials). These instruments are shown in Figure A.1.

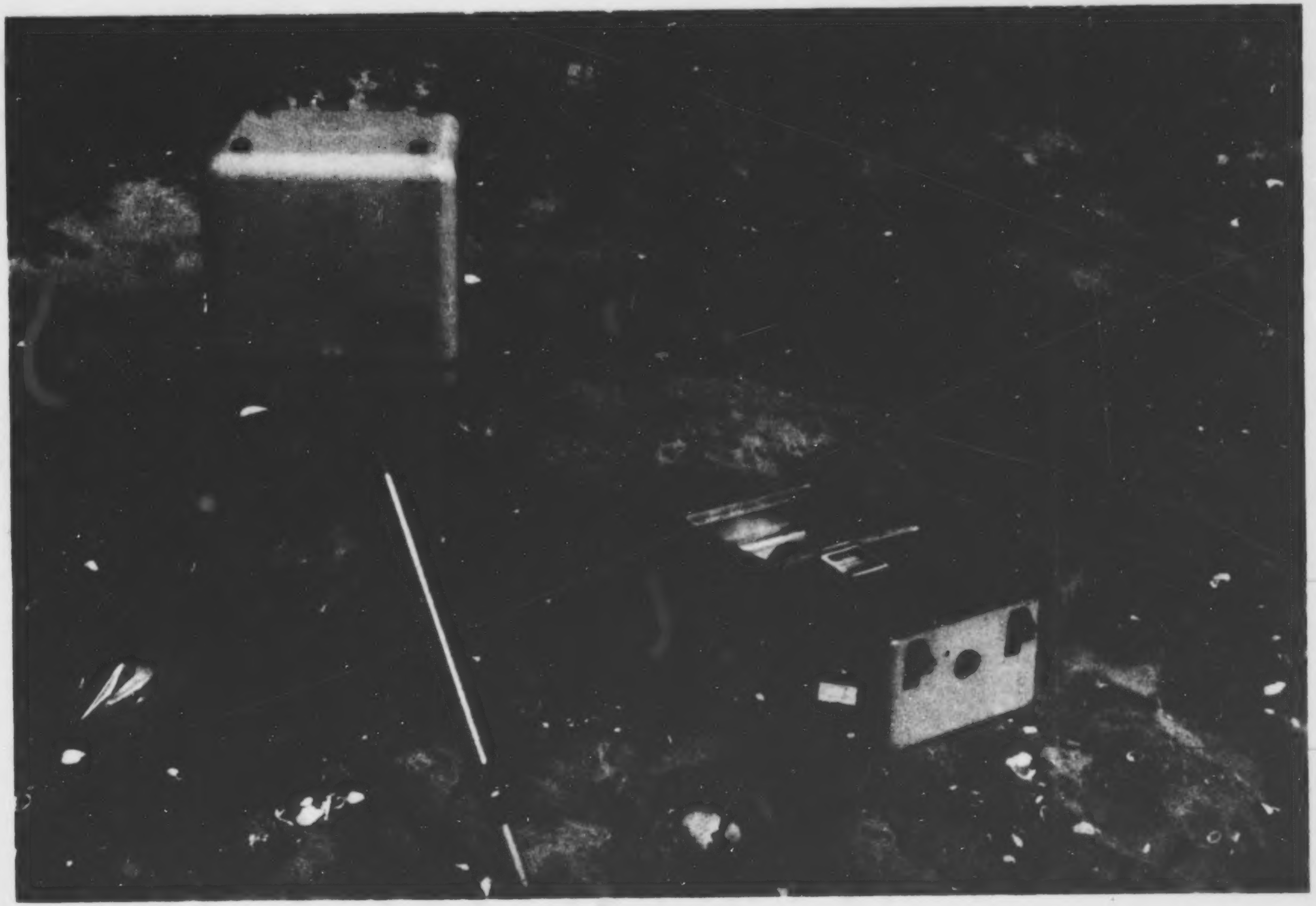

Figure A.1 - Gamma Radiation Measurements
(L to R: Reuter-Stokes Pressurized Ion Chamber
and Ludlum Model 125 Micro R Meter)

III. RADON AND DECAY PRODUCT MEASUREMENT TECHNIQUES

Two techniques were employed for measuring the radon decay product levels within structures, TLD air samplers and track-etch badges.

a) Radon Progeny Integrating Sampling Unit (RPISU)

The primary air sampling system used by the Environmental Protection Agency, Office of Radiation Programs (EPA/ORP) was developed by Colorado State University, Fort Collins, Colorado. It is known as the Radon Progeny Integrating Sampling Unit (RPISU) and utilizes the detection techniques of thermoluminescent dosimetry (TLD). This device is shown in Figure A.2.

The air pump is located inside two pieces of polyvinyl chloride (PVC) pipe. The PVC pipes are of different diameters and the area behind the pipes is filled with sound deadening material. The pump is attached to a sampling head which is located outside of the pump housing. This sampling head, which is actually a hypodermic syringe filter holder, contains the TLD's. The filter head is made up at the EPA facility in Las Vegas, Nevada, or Montgomery, Alabama, and packaged in a small 3" x 5" envelope. This envelope also provides space for the entry of the necessary field data.

During operation, air is pulled through the sampling head and the particulate material containing the radon decay products is trapped on a one-half inch filter. A TLD (CaF:Dy) is located in the airstream directly before the filter and the alpha energy from the decay of the

Figure A.2 - Radon Progeny Integrating Sampling Unit (RPISU)

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radon daughters is recorded by this TLD. A second TLD, separated from the first by a stainless steel washer, is also located in the filter head. The first TLD is referred to as the alpha TLD and the second as the gamma TLD.

The filter head is placed on the sampler, and the starting sampler information consisting of the reading on a running time meter, a location number, date and time, and air flow (measured by a calibrated rotometer) is filled in on the envelope. The sampler is usually left in place for one week. Information on date, time, and flow rate at cut-off is entered on the envelope. The envelope with the filter head is then returned to the Las Vegas facility. The head is taken apart, the TLD's read out on a Harshaw TLD reader, a data form completed and sent for computer analysis, and the finished printout containing the calculated working level* (WL) retrieved.

The working level is calculated by providing a working level-liter/nanocoulomb (WL-l/nC) conversion factor for the TLD reader, nC readout for gamma and alpha TLD, the running time of the sample, the on and off air flow rates and the number of the rotometer used.

The net nC value is obtained by subtracting the gamma TLD nC (background gamma radiation) from the alpha TLD nC (alpha decay energy plus background). This value, multiplied by the conversion factor and divided by the correct air balance, produces the WL value average for the period of exposure.

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*WL - The working level is defined as the potential alpha energy from the short-lived daughters of radon which will produce 1.3×10^5 MEV in one liter of air.

b) Track-etch Films

The track-etch badge consists of a one-half inch by one inch plastic chip which is coated with cellulose nitrate. As radon and its decay products are formed, alpha particles are produced. When the alpha particles strike the cellulose nitrate, a record of their passage is made. The badges were each numbered, and two of the badges were usually mounted on a cardboard card which can be positioned on a wall. The badges were left in place from six months to a year and collected, then dipped in a caustic solution (NaOH) or "etched". The alpha particle's passage becomes an etched track, visible with the use of a microscope.

Each badge, after etching, was read by a technician using a light microscope with a calibrated field. The number of tracks observed was recorded and the tracks per square millimeter (T/mm^2) were calculated. This value was then compared to a calibration curve and the working level hours (WL-h) associated with the number of tracks observed was obtained. The WL short-lived daughters of radon which will produce 1.3x10^5 MeV in one liter of air was then calculated, using the number of hours the badge was in the sampling location.

The badge has the advantage of being a passive dosimeter. That is, it is put in place and picked up, but no maintenance is required during the sampling period (no moving parts). However, it has the disadvantage of measuring or recording not only the alpha energy given off by radon, but also by polonium-218 (radium A) and polonium-214 (radium C). Since the alpha energy from radon is not a portion of the alpha energy used to determine the WL (the radon daughters and not the radon-222 itself are the prime contributors to adverse health impact), the system must be calibrated so that the complement from radon can be subtracted. This calibration will be discussed in depth in a later section.

IV. INFORMATION COLLECTION AND ORGANIZATION

In the initial survey of structures built on reclaimed phosphate land, track-etch films were placed in 85 structures built on reclaimed land and in 40 structures built on nonreclaimed land. Structures surveyed consisted primarily of private dwellings; however, local health department buildings and a few office buildings were also surveyed.

At each structure, data were obtained regarding its classification (residence, business, etc.), construction type (basement, slab, crawlspace, etc.), number of levels, material (masonry, non-masonry), and whether it was air conditioned. A map was made of each structure showing the indoor and outdoor external gamma radiation levels. This data was computer coded according to location identification number and address. Data were added to the computer file on the indoor radiation level in the structure for both the RPISU system or track-etch films. Printouts are accessible by keying the file in several different ways, depending upon the specific variable of interest.

After noting elevated levels in some structures in September 1975, the track-etch data base was expanded in November 1975. Since that time the State of Florida has selected 997 structures for study either by TLD air pump, track etch film or both. Further, as time has become available for using the air pumps in additional structures, they have been added to the TLD air pump data base. The information from the study collected as of January 20, 1978, for TLD air pump data are listed in the Annex.

APPENDIX B

CALIBRATION OF TRACK-ETCH FILMS

I. DEPLOYMENT OF DOSIMETERS

The calibration of the track-etch films used in the study was accomplished by randomly selecting 23 structures and installing track-etch films and air sampler (RPISU) devices in each of them. A total of two or three films were used in each structure. In the structures one film was deployed for a period of about one year and the other two films were deployed for consecutive six month intervals coincident with the film which was in place for a year. The RPISU devices were operated for approximately a one week period for four to seven weeks during the year, with at least one week in each of the four seasons.

II. STATISTICAL ANALYSIS OF THE DATA

The data set for statistical analysis included 41 points (N) from 23 locations, using two types of film measurements. The first was the set of values of track density (T) for films exposed for the entire year, while the second was constructed by summing results of two films exposed in consecutive six month periods at the same location. These two types of measurements did not differ significantly. Corresponding air sampler measurements (RPISU) for indoor working levels (W) are averages of from four to seven measurements taken during the study period at each of the 23 locations. The data was analyzed with the air sampler data as the independent variable and the track-etch film data as the dependent variable. The data are listed in Table B.1.

Table B.1. Data for Indoor Radon Study

Location	Track-etch density (tracks /mm^2) 1st six mos.	2nd six mos.	1st+2nd	Air Sampler entire year	(WLh)
70050	7.6	6.45	14.05	16.20	77
70051	5.6	2.48	8.08	5.62	163
70076	26.8	29.09	55.89	49.91	605
70079	32.2	19.00	51.20	34.54	596
70082	1.3	15.70	17.00	16.69	182
70084	1.0	3.64	4.64	.83	173
70087	5.3	5.29	10.59	4.63	340
70094	-	-	-	31.07	304
70101	-	-	-	3.80	153
70103	6.5	4.30	10.80	10.08	306
70105	10.9	6.11	17.01	7.77	373
70107	-	-	-	52.88	661
70110	28.9	22.64	51.54	61.97	698
70118	3.5	1.65	5.15	1.32	107
70134	1.32	2.48	3.80	5.45	19
70135	1.16	8.43	9.59	2.31	10
70136	.5	1.16	1.66	1.82	10
70137	1.98	8.10	10.08	8.92	10
70169	5.95	8.76	14.71	9.42	238
70170	7.11	6.11	13.22	-	69
70172	15.37	3.80	19.17	-	314
70175	1.82	4.30	6.12	4.46	19
70180	2.81	2.48	5.29	4.30	28

In order to arrive at an equation which best fits the relationship between track density on the films and air pump measurements, the following regression analyses were performed on the data given in Table B.1:

Option 1

$$T = 0.4 + .069\ W$$

(t=0.2) (t=11)

$R^2 = 0.87$

F = 124

N = 41

Option 2

$T = -19.5 + 7.57 \ln W$

$(t= -2.7)\ (t=5.1)$

$R^2 = .63$

$F = 26$

$N = 41$

Option 3

$\ln T = 1.4 + .0037W$

$(t=7)\ (t=7.3)$

$R^2 = 0.76$

$F = 53$

$N = 41$

Option 4

$\ln T = .09 + .46 \ln W$

$(t=.2)\ (t=5.0)$

$R^2 = .62$

$F = 25$

$N = 41$

These options cover the obvious linear and nonlinear cases that could be considered. (The t statistic is used to test the statistical significance of its corresponding parameter. R^2 is the proportion of the total variation in the dependent variable explained by the regression equation. The F statistic tests the presence of a relationship between the dependent and independent variables of the regression equation.)

Using the R^2 and F statistics as decision criteria for choosing the best overall fit and prediction ability, Option 1 appears to be the best. That is, the simple linear form of the relationship between track-etch and air pump data appears to fit and predict better than either the log-linear or log-log forms. It can be seen that Option 2 is consistent with the null hypothesis that the intercept is equal to zero, based on the t value. This result appears to confirm the theory put forth by D.B. Lovett that, "the track density resulting from the exposure of films to alpha particle activity is directly proportional to the time integral of the total alpha particle activity of the atmosphere to which it was exposed" (Lo 75). Therefore, a final regression was run in which the intercept is omitted:

Option 5

$$T = .070\,W$$
$$(t=11)$$
$$R^2 = .75$$
$$F = 12$$
$$N = 41$$

This is taken to represent the "best" fit between the track density on the film and the TLD air pump measurements. The 95 percent confidence interval for a predicted W from a measured T, based on option 5 is:

$$\frac{T}{.069} \pm 250 \qquad .99 + \frac{T^2}{20,000}$$

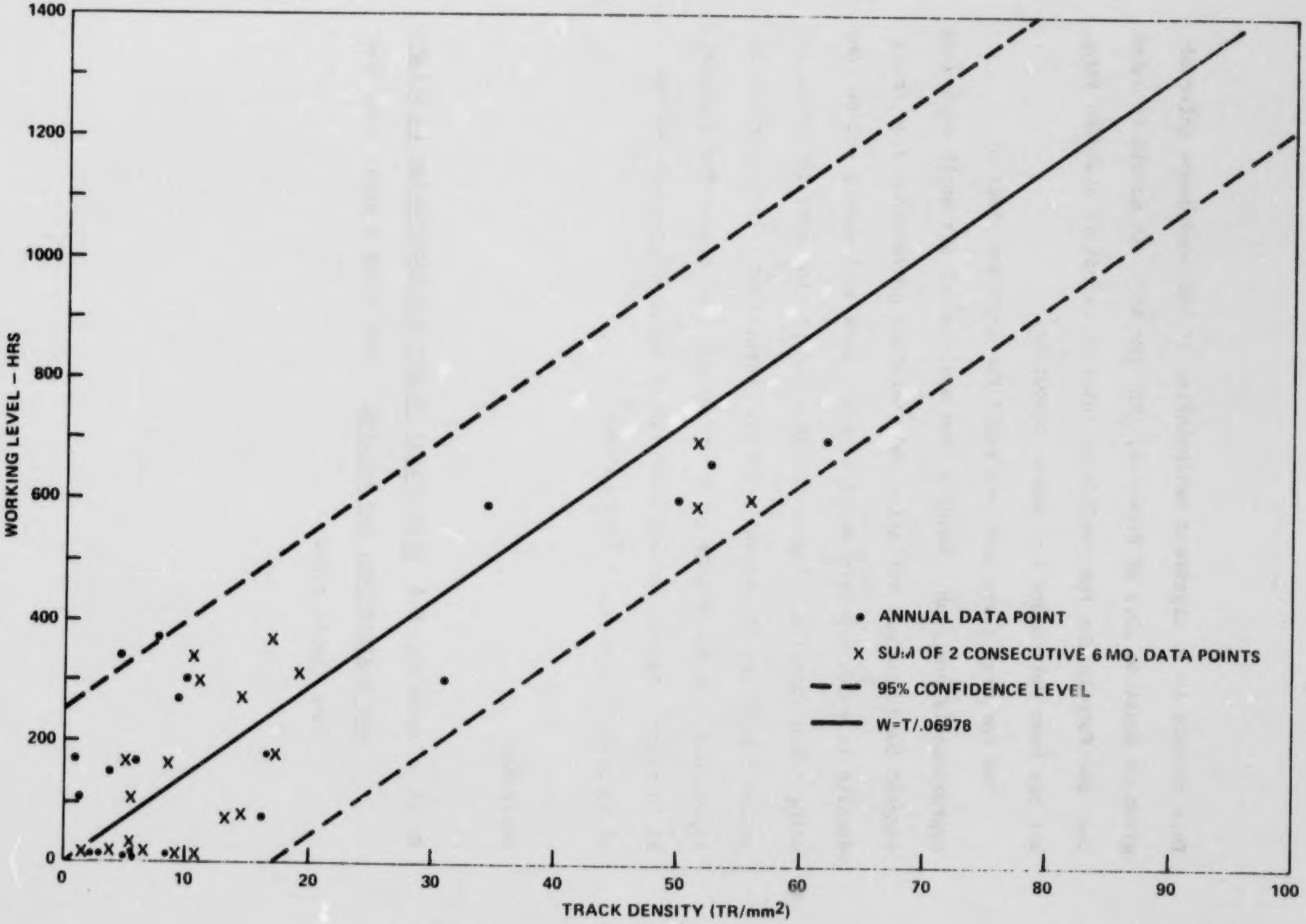
This formula is an algebraic manipulation of the confidence interval given in Equation 10.5 of Brownlee, 1965 (Br 65). It should be noted that the formula for the confidence interval is not in standard form, but has been rearranged for easier computing.

The formulas given here are valid for exposure times of approximately one year. Results from analyses of six month exposures suggest some seasonal variation and therefore conversions from track density to radon exposure based on short term data should not be done using these formulas. Figure B.1 is a plot of the equation given in option 5 with the 95 percent intervals identified. As the origin is approached, the percentage of error rapidly increases. For example, at 60 tr/mm^2, the 95 percent interval is about ±30 percent whereas at 20 tr/mm^2 it is about ±100 percent.

Reference:

Br 65 Brownlee, K.A. Statistical Theory and Methodology in Science and Engineering, 2nd Edition. John Wiley & Sons, Inc.: New York (1965) p.362.

Figure B.1



CALIBRATION FORMULA AT 95% CONFIDENCE LEVEL

APPENDIX C

RADIATION EXPOSURE CONTROL MEASURES

I. INTRODUCTION

This assessment is extracted primarily from a survey of available measures conducted and published by the Agency in November 1976 (Fi 76). It includes an update on control technology costs that have changed since publication of the survey. This evaluation focusses on state-of-the-art radon decay product control measures for proposed structures which have radon transport through the foundations. Several of these measures have similar application for reduction of radon decay product concentrations in existing structures as well as reduction of external gamma exposure in both new and existing structures. Five available measures are assessed for cost-effectiveness: ventilation, polymeric sealants, ventilated crawl space construction, excavation, and improved slab construction, the latter two having dual application for gamma and radon. These measures will be discussed in the context of existing and planned structures.

II. AVAILABLE TECHNOLOGIES

a) Utilization of Air Cleaners

Air cleaners are designed to remove particulates from the circulating air of building interiors. The type of air cleaner used depends upon the particle size and shape, specific gravity, concentration of the particulates, and the efficiency of removal desired. Of these, the particle size, along with overall filtering efficiency required, is the most important characteristic by which an air cleaner is chosen.

Electronic air cleaners use electrostatic precipitation principles to collect particulate matter. Unlike their industrial counterparts, residential electronic air cleaners operate on standard house current and with normal operation use electricity at the same rate as a 50-watt lightbulb. The performance of electronic air cleaners depends upon the rate of air flow and the quality of installation. A number of commercially available models are designed to meet these performance parameters, as well as others such as the volume of air to be cleaned and the size of the heating or cooling unit.

As no data are available concerning the efficiency of air cleaners in reducing the concentration of radon daughters, modeling was performed to make such an estimation (Fi 76). These calculations show that theoretically, most of the radon daughter level reduction occurs at effective ventilation rates of less than two air changes per hour (approximately 70 percent). Therefore, assuming that natural infiltration accounts for one air change per hour, air cleaners, which can effectively handle ventilation rates of about one to two air changes per hour, would have a relatively marginal effect on working level reduction. For HEPA and electronic air cleaners, a 38 percent reduction in the equilibrium radon daughter working levels was calculated. For HEPA filters, though, increased effective ventilation rates could lead to an increased tracheobronchial dose (and therefore a potentially higher total lung dose), due to the resulting increase in the free ion fraction of radon daughters (Ja 72).

For a combined electronic air cleaner and outside air exchange system, an efficiency of 62 percent was calculated for working level reduction. This model assumes a flow rate through the system of 1.5 air changes per hour and about 25 percent makeup air.

b) Polymeric Sealants

Ideally, if one could completely seal all of the floor and wall space below ground level for a structure with radon diffusing through the floor, the problem would be largely alleviated. The radon gas that would normally diffuse through the floor would be trapped by this barrier so that it would decay in the structural material and not enter the structure's atmosphere.* Polymeric sealants, having low permeability to radon gas, have been proven to be effective in reducing in-house radon progeny when properly applied. An EPA funded study by Culot, _et_ _al._, (Cu 73) showed that radon diffusion into a structure could be reduced by more than one half by utilizing an epoxy sealant. An important finding was that a significant reduction of radon diffusion into structures could be obtained only in a situation free of other major pathways for radon. From past analyses with test structures on slabs, as well as experience with remedial action in structures in Grand Junction, Colorado, it was determined that such pathways do exist and are common in typical residential structures. One such pathway is minute cracks in the concrete slab at the juncture of the slab and wall, another is the channel through which pipes and drains enter the slab. The analyses and field experience have shown that without complete sealing of these pathways with a radon-impermeable base, only a relatively small working level reduction could be obtained. The thoroughness of sealant application, then, is of prime importance in the implementation of this control measure.

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*There is a whole-body gamma exposure related to such decay, although in regard to potential health effects it is insignificant in comparison to radon daughter alpha exposure in the lung. From past field studies, fractional gamma increases of 2 to 20 percent were measured for a 4-inch concrete slab after sealant application.

An efficiency range of 70-90 percent radon progeny reduction for polymeric sealants was derived from test data by Culot, et al., (Cu 73). Their experiments involved the use of sealed tanks above a sealed concrete slab with uranium tailings underneath. Assuming an equilibrium radon progeny concentration over the slab equal to 10 percent of the source term under the slab, which they had previously determined, the range of reduction was approximately 75-99 percent using polyester styrene, polyester resin, and Omnitech* polymers. From a similar experimental analysis, Auxier, et al., (Au 74) suggests that an 88 percent reduction in airborne radon progeny could be obtained. As these reductions were achieved in an experimental lab situation, the reduction range of 70-90 percent was chosen as a conservative approximation of actual residential application. Again, the degree of reduction achievable would be dependent upon the method and thoroughness of application.

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*Omnitech Industries, Inc.

c) Ventilated Crawl Space Construction

The function of building a crawl space for radon progeny control is to provide a highly ventilated space between the soil surface and the overlying structure in which the emanating radon gas can be diluted or removed before diffusion into the structure. The degree to which such ventilation is effective is dependent upon the number of air changes per unit time within the enclosure below the floor. Assuming that a wooden floor would allow radon gas to diffuse readily, the fractional reduction of radon gas diffusion into the structure would be proportional to the reduction in partial pressure of the radon in the crawl space due to ventilation. There are two means by which the ventilation characteristics of a crawl space can be enhanced, involving passive and nonpassive measures. First, the crawl space can be constructed utilizing oversized, properly spaced vents on all sides of the structure. Second, a fan could be set up for forced ventilation of the crawl space, thereby establishing a lower limit of ventilation. Although there is no readily available data concerning the magnitude or range of the ventilation rate which could be achieved, with proper construction it could compare favorably with a well-ventilated house (2-4 air changes per hour). Assuming such ventilation rates, radon daughter working level reductions of 80 percent or more would be possible. The level of reduction achievable could be increased, if desired, through the use of a radon impervious barrier in the floor. Such a barrier, possibly in the form of a polymeric sealant underlying a seamless tile floor, would have side advantages such as moisture proofing and a reduction in heating and air-conditioning infiltration loss.

d) Site Excavation and Fill

A ten-foot layer of soil with a relaxation length* of 4.9 feet (for moist packed earth and dry packed uranium tailings with a diffusion coefficient of 5×10^{-2} cm/s) can be as much as 80 percent effective at reducing radon emanation from the ground surface (Sc 74). Such data indicate that by removing this depth of reclaimed phosphate soil and replacing it with non-uraniferous soil of the same density and porosity, approximately 80 percent of the radon would be retained in the ground. If such a procedure were done for a home site on phosphate land, the diffusion rate of radon into the structures to be built would then be proportionally less, assuming negligible lateral radon diffusion.**

---

*The depth of a uniform layer of material of the same density in which a diffusing gas (radon in this case) is reduced in concentration by a factor of "e" (2.703).

**Although no field studies have been performed concerning lateral diffusion, the cost-effectiveness calculations in Section V allow for excavation to a distance of three feet from the foundation.

With regard to gamma exposure reduction, packed earth at 1.6 g/cm^3 density has a tenth value layer of 13 inches (i.e., the gamma radiation level is reduced by a factor of ten over this thickness at the assumed density). Therefore, an equivalent 80 percent reduction in exposure is achievable with only 9 inches of soil, with a 99+ percent reduction for ten foot depth. These estimates assume no contribution from terrestrial sources external to excavated soil.

e) Improved Slab Construction

Another technique by which the overall effectiveness of radon daughter control measures could be enhanced would be improving the quality of slab (quality control, reinforcement and thickness). As the pore size present in the cement has a large influence on its radon stopping ability, utilizing concrete with a low water to cement ratio by weight (W/C) and dense aggregate material (such as granite or marble) would decrease radon permeability.

Increasing the thickness of the concrete slab would likewise reduce the radon diffusion rate, assuming this is the major pathway. As radon gas has a relaxation distance of about 5 cm (2 inches) in a standard concrete (density = 2.35 g/cm^3), by doubling the thickness of a normal 4-inch slab to 8 inches, an 80 percent reduction in exhalation is possible. For controlling gamma irradiation through the foundations, increasing the thickness of the concrete slab would lead to a 70 percent gamma reduction. This estimate is based on concrete with 6 percent porosity, with an increase in slab thickness from 4 to 8 inches. Unlike radon emanation, the presence of cracks would not lessen the efficiency of reduction.

III. COST ANALYSIS FOR IDENTIFIED CONTROL TECHNOLOGIES

A cost analysis on the utilization of radon daughter control technology is critical to any decision-making process in this area. As with pollution control equipment in industry, the cost of control measures would probably be passed on to the consumer, or the homeowner in this case. In order to minimize expenses, the builder must first determine, from available data, which control measures reduce the radon progeny concentrations down to acceptable residential levels, and second, which of these measures can be implemented and maintained at the least cost to him.

The cost figures utilized in this analysis, as shown in Table C-1, are best average estimates based on data derived from literature, government, and private industry. Because of their different sources, a small degree of variability is to be expected for the actual cost of application in specific localities of the country. Another source of variability is inherent in the use of an average value. Such an estimate is applicable only for an average site and, therefore, cannot be generally applied. All cost figures utilized in this analysis are adjusted to present value (6 percent annual discount rate applied).

TABLE C. 1

ESTIMATED AVERAGE COST OF CONTROL MEASURES FOR STRUCTURES CONSTRUCTED ON FLORIDA PHOSPHATE LAND*

CONTROL MEASURE	CAPITAL COST	ANNUAL MAIN-TENANCE COST	ANNUAL ELECTRICAL COST	TOTAL AVG. ANNUAL OPERATING COST	PRESENT WORTH OF TOTAL COST (70 YRS)
EXISTING STRUCTURES					
AIR CLEANERS:					
HEPA	$400	$100	UNDEFINED	$100	$2050
ELECTRONIC	$350	$25+ ***	$10	$35+	$900
ELECTRONIC AND AIR EXCHANGER	$900	$25+	$80	$105+	$2600
POLYMERIC SEALANT:	$600-$1950	UNDEFINED	NONE	NONE	$600-$1950
PLANNED STRUCTURES					
VENTILATED CRAWL SPACE:	$550	NONE	UNDEFINED	NONE	$550
EXCAVATION AND FILL: (TO 10' DEPTH)					
COMMERCIAL FILL RATE –					
FOR 80% RADON REDUCTION (INCLUDES 99% GAMMA)	$3250-$5500	NONE	NONE	NONE	$3250-$5500
FOR 80% GAMMA REDUCTION	$250-$400	NONE	NONE	NONE	$250-$400
W/NOMINAL FILL COST –					
FOR 80% RADON REDUCTION (INCLUDES 70% GAMMA)	$2550-$2900	NONE	NONE	NONE	$2550-$2900
FOR 80% GAMMA RED	$200	NONE	NONE	NONE	$200
IMPROVED SLAB CONSTRUCTION:					
FOR 80% RADON REDUCTION (INCLUDES 70% GAMMA)	$550	NONE	NONE	NONE	$550
FOR 80% GAMMA REDUCTION	$600	NONE	NONE	NONE	$600

*ASSUMMING 1500 SQUARE FEET FLOOR AREA AND 1977 DOLLAR VALUE (6% DISCOUNT PER YEAR APPLIED); ALL FIGURES ARE FOR RADON PROGENY REDUCTION EXCEPT WHERE OTHERWISE NOTED

**SEE TEXT

***"+" SIGNIFIES THAT THE ESTIMATE GIVEN IS MOST LIKELY A MINIMAL ONE, ALTHOUGH THE ACTUAL AVERAGE IS UNDEFINABLE USING AVAILABLE COST DATA

There are numerous components of the total cost, both tangible and intangible, which will be considered. The capital cost is the most important component to the prospective builder, which would be incurred in order to implement the control measure. With mechanical equipment such as air cleaners, maintenance and replacement costs also become important in calculating the total cost. As most equipment of this type has a useful life of roughly ten years, some maintenance and possibly replacement will be required over the average life span of a building. Another component is electrical cost which is, again, primarily associated with the use of mechanical air cleaning equipment. Due to probable increased air infiltration in homes with crawl spaces, there would be additional electrical costs as a result of the corresponding increase in the use of air-conditioners or electrical heating units.

APPENDIX C REFERENCES

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APPENDIX D

EVALUATION OF FIELD DATA

I. Evaluation of Radon Decay Product Level Data

D.1.1 General

Data on indoor radon decay product levels were obtained for over 200 structures throughout Central Florida. However, not all of these data are useful in describing the radiological situation. In order to represent a year's exposure condition in a structure, it is desirable to operate the air pumps (RPISUs) four to six times spaced throughout the year for approximately a week each time. This proved to be difficult to achieve in many structures for several reasons. First, some residents refused to allow the devices to be operated for those time periods. Second, smoking and other environmental factors within a structure sometimes clogged the filters and automatically stopped the pumps after only a few hours of operation. And third, exchanges of property sometimes precluded necessary followup measurements.

During the study it was also learned that, in addition to not being representative of long time periods of exposure, short air pump operational times (generally less than 24 hours) sometimes were predictive of indoor radon decay product levels considerably higher than extended runs in the same structure. All of the reasons for this observed phenomenon have not been discerned, although to minimize the use of erroneous data, short run times were not utilized to determine structure averages. In order to further improve the validity of the measurements made, we have decided to report average indoor radon decay product levels from structures with air pump operating times of more than 24 hours. Also, the three or more measurements must total more than 125 hours of combined operation to be included.

Using the above data selection criteria, 133 structures were identified from those in the original EPA pilot study and the group chosen by DHRS. TLD's from these air pumps were analyzed by the Eastern Environmental Radiation Facility in Montgomery, Alabama, the Radiation Office in Las Vegas, Nevada, and Department of Health and Rehabilatative Services, Orlando, Florida. All of the data from these sources were combined, with each of these groups participating in quality control checks and intercalibrations. As a result of such intercomparisons, all the data is believed to be within ±30 percent of the true value. This is very important to consider when trying to draw conclusions about the need for remedial action in a structure.

Figure D.1 depicts the breakdown of the observed indoor radon decay product data according to percentage distribution of the mean gross indoor level for the entire 133 structures in the composite EPA-DHRS population. This data is summarized in Table D.1 by percentile in excess of selected radon decay product levels for the EPA, DHRS, and composite groups; and for houses on reclaimed or mineralized land only.

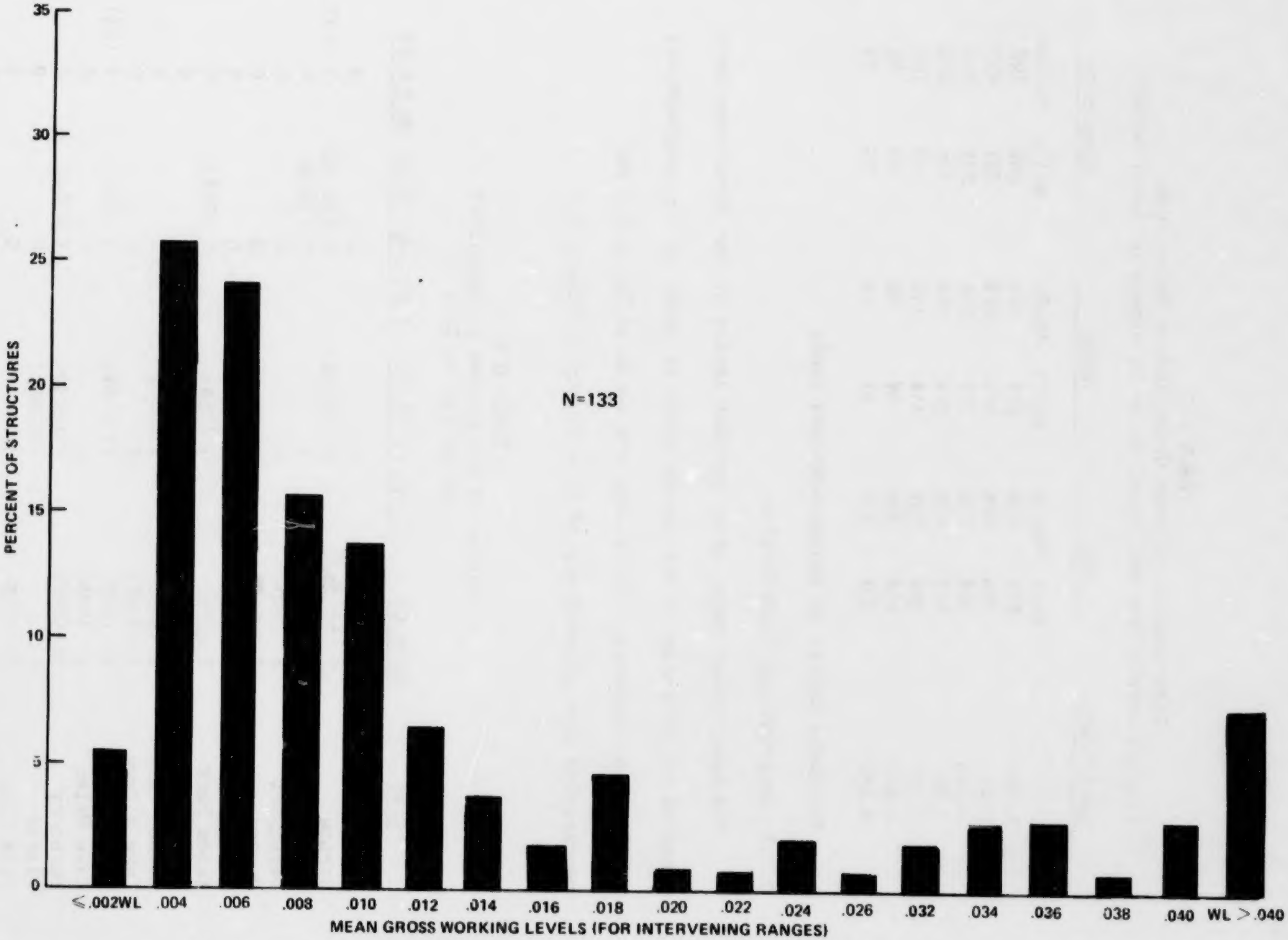

Figure D.1 PERCENT DISTRIBUTION OF TLD AIR SAMPLING MEASUREMENTS

TABLE D.1
Distribution of Mean Gross Indoor Radon Decay Product Levels (percent equal to or in excess of level noted)

Level (WL)	EPA		DHRS		Composite	
	N=22	*N=15	N=111	*N=89	N=133	*N=104
0.005	64%	93%	65%	76%	65%	79%
0.01	55%	80%	31%	37%	35%	43%
0.015	50%	73%	17%	21%	23%	29%
0.02	41%	60%	14%	18%	19%	24%
0.030	36%	53%	11%	13%	15%	19%
0.040	23%	33%	3%	3%	6%	8%
0.050	23%	33%	2%	2%	5%	7%

*Excludes houses on non-mineralized lands

D.1.1 Geographical Distribution

The mean indoor radon decay product levels in the structures were examined to determine if any trends could be noted in the geographical distribution patterns. These data are shown in Table D.2 and represented on a general map of Polk County in Figure D.2.

TABLE D.2
Number of Structures in Specified WL Ranges by City

City	WL<0.01	0.01≤ WL <0.03	0.03≤WL < 0.05	WL≥0.05	N
Auburndale	2 (100%)	0	0	0	2
Bartow	2 (22.2%)	2 (22.2%)	2 (22.2%)	3 (33.3%)	9
Bradley Junction	0	0	1 (100%)	0	1
Davenport	2 (100%)	0	0	0	2
Dundee	2 (100%)	0	0	0	2
Eagle Lake	1 (100%)	0	0	0	1
Eaton Park	2 (50%)	1 (25%)	1 (25%)	0	4
Fort Meade	1 (33.3%)	2 (66.7%)	0	0	3
Haines City	9 (90%)	1 (10%)	0	0	10
Lake Alfred	1 (100%)	0	0	0	1
Lakeland	42 (68%)	11 (18%)	5 (8%)	4 (6%)	62
Lake Wales	3 (100%)	0	0	0	3
Mulberry	16 (64%)	5 (20%)	4 (16%)	0	25
Pierce	0	1 (100%)	0	0	1
Polk City	2 (100%)	0	0	0	2
Winter Haven	5 (100%)	0	0	0	5
TOTAL	90	23	13	7	133

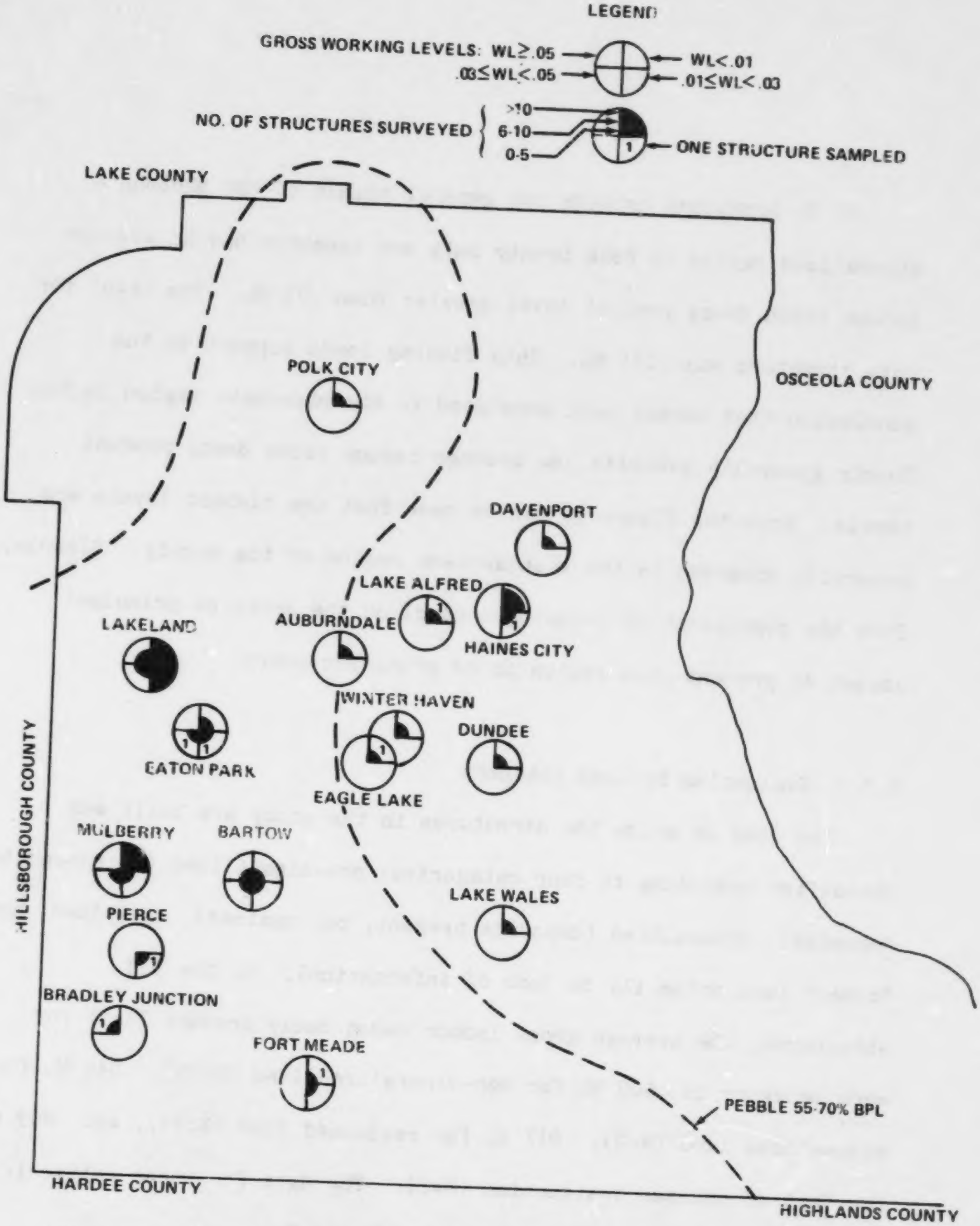
LEGEND
GROSS WORKING LEVELS: WL≥.05
.03≤WL<.05
WL<.01
.01≤WL<.03
NO. OF STRUCTURES SURVEYED
>10
6-10
0-5
1
ONE STRUCTURE SAMPLED
LAKE COUNTY
OSCEOLA COUNTY
HILLSBOROUGH COUNTY
HARDEE COUNTY
HIGHLANDS COUNTY
POLK CITY
DAVENPORT
LAKE ALFRED
AUBURNDALE
HAINES CITY
LAKELAND
WINTER HAVEN
DUNDEE
EATON PARK
EAGLE LAKE
MULBERRY
BARTOW
LAKE WALES
PIERCE
BRADLEY JUNCTION
FORT MEADE
PEBBLE 55-70% BPL

Figure D.2 AVG INDOOR RADON PROGENY WORKING LEVEL DISTRIBUTION (GROSS) FOR POLK COUNTY, FLORIDA (N=133)

Of 25 locations outside the general bounds of the phosphate mineralized region in Polk County only one location had an average indoor radon decay product level greater than .01 WL. The level for this structure was .011 WL. This finding lends support to the conclusion that normal soil unrelated to the phosphate region in Polk County generally exhibits low average indoor radon decay product levels. From the figure it can be seen that the highest levels are generally observed in the southwestern region of the county. Clearly, from the standpoint of focusing control on the areas of principal impact at present this region is of primary concern.

D.1.3 Evaluation by Land Category

The land on which the structures in the study are built was classified according to four categories: non-mineralized (no phosphate deposits), mineralized (deposits present, but unmined), reclaimed, and "other" (due primarily to lack of information). Of the 133 structures, the average gross indoor radon decay product level for each category is .003 WL for non-mineralized land (N=29), .015 WL for mineralized land (N=9), .017 WL for reclaimed land (N=93), and .009 WL for land of unknown designation (N=2). The data for these categories are given in Table D.3 and graphed in Figure D.3.

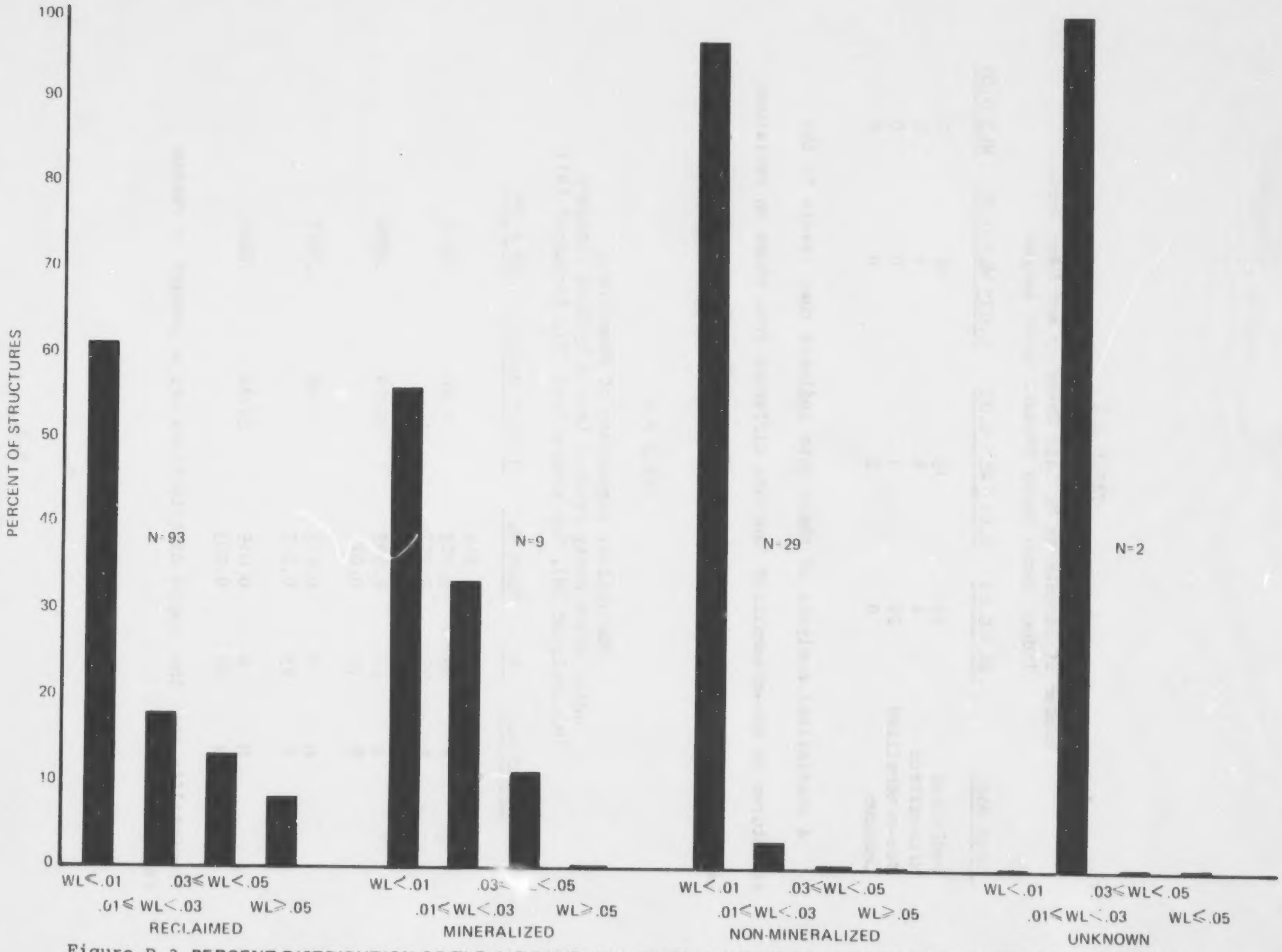

Figure D.3 PERCENT DISTRIBUTION OF TLD AIR SAMPLING MEASUREMENTS BY LAND CATEGORY AND GROSS WORKING LEVEL RANGE

TABLE D.3

Number of Structures by Land Category and Mean Gross Indoor Radon Decay Product Level Ranges

Land Use	$WL < 0.01$	$0.01 \leq WL < 0.03$	$0.03 \leq WL < 0.05$	$WL \geq 0.05$
Reclaimed	55	19	12	7
Mineralized	4	4	1	0
Non-mineralized	28	1	0	0
Unknown	0	2	0	0

A statistical analysis of these data indicate that levels in the structures on non-mineralized land are different from those on reclaimed land at the 99 percent confidence level as shown in Table D-4:

TABLE D.4

Statistical Comparison of Mean Gross Indoor Radon Decay Product Levels by Land Category (Mineralized (M), Non-mineralized (N), Reclaimed (R))

Land Use	N	Mean WL	F-test value	PR ≥ F*
M	9	0.015	6.90	.0014
N	29	0.003		
R	93	0.017		
N	29	0.003	13.24	.0004
R	93	0.017		
M	9	0.015	0.09	.7677
R	93	0.017		
M	9	0.015	29.46	.0001
N	29	0.003		

*Probability that the sample distributions are a product of random variability.

Further, it is observed that the levels in structures on mineralized land are not different from reclaimed land at the 90 percent confidence level. This suggests that structures on mineralized land may present similar indoor radon decay product levels as reclaimed land. Therefore, based on present information, it would be extremely difficult to differentiate the two categories with respect to control recommendations.

D.1.4 Evaluation by Structure Type

The data was classified according to four structure types: basement, slab on grade, crawl space, and trailer. Of the 133 structures, the average gross indoor radon decay product level for each structure type is 0.02 WL (Basement, N=4), 0.014 WL (slab on grade, N=102), 0.010 WL (crawl space, N=13), and 0.008 WL (trailer, N=14). The sample distribution by selected working level ranges is provided in Table D.5.

TABLE D.5
Number of Structures by Structure Type and Mean
Gross Indoor Radon Decay Product Level Ranges (N=133)

Structure Type	$WL < 0.01$	$0.01 \leq WL < 0.03$	$0.03 \leq WL < 0.05$	$WL \geq 0.05$
Basement	2	0	2	0
Slab	66	20	9	7
Crawlspace	10	2	1	0
Trailer	11	2	1	0
TOTAL	89	24	13	7

The data for these structure types are summarized in Figure D.4. Review of these data do not indicate any statistically significant differences among the four structure types at the 40 percent confidence level, as shown in Table D.6. Therefore, though inspection of the data suggests that basement and slab-on-grade structures have higher indoor radon decay product levels, this cannot be shown to be statistically significant. One of the problems in showing such significance is the small number of structures in the categories other than slab-on-grade.

TABLE D.6

Statistical Intercomparison of Mean Gross Indoor Radon Decay Product Levels by Structure Type (Basement (b), Slab (s), Crawlspace (c), Trailer (T))

Structure type	N	Mean WL	F-test value	PR > F *
B	4	0.020	0.99	.4012
S	102	0.014		
C	13	0.010		
T	14	0.008		
B	4	0.020	0.27	.6035
S	102	0.014		
C	13	0.010	0.14	.7067
T	14	0.008		
S	102	0.014	0.87	.3523
C	13	0.010		
S	102	0.014	1.70	.1948
T	14	0.008		

*Probability that the sample distributions are a product of random variability

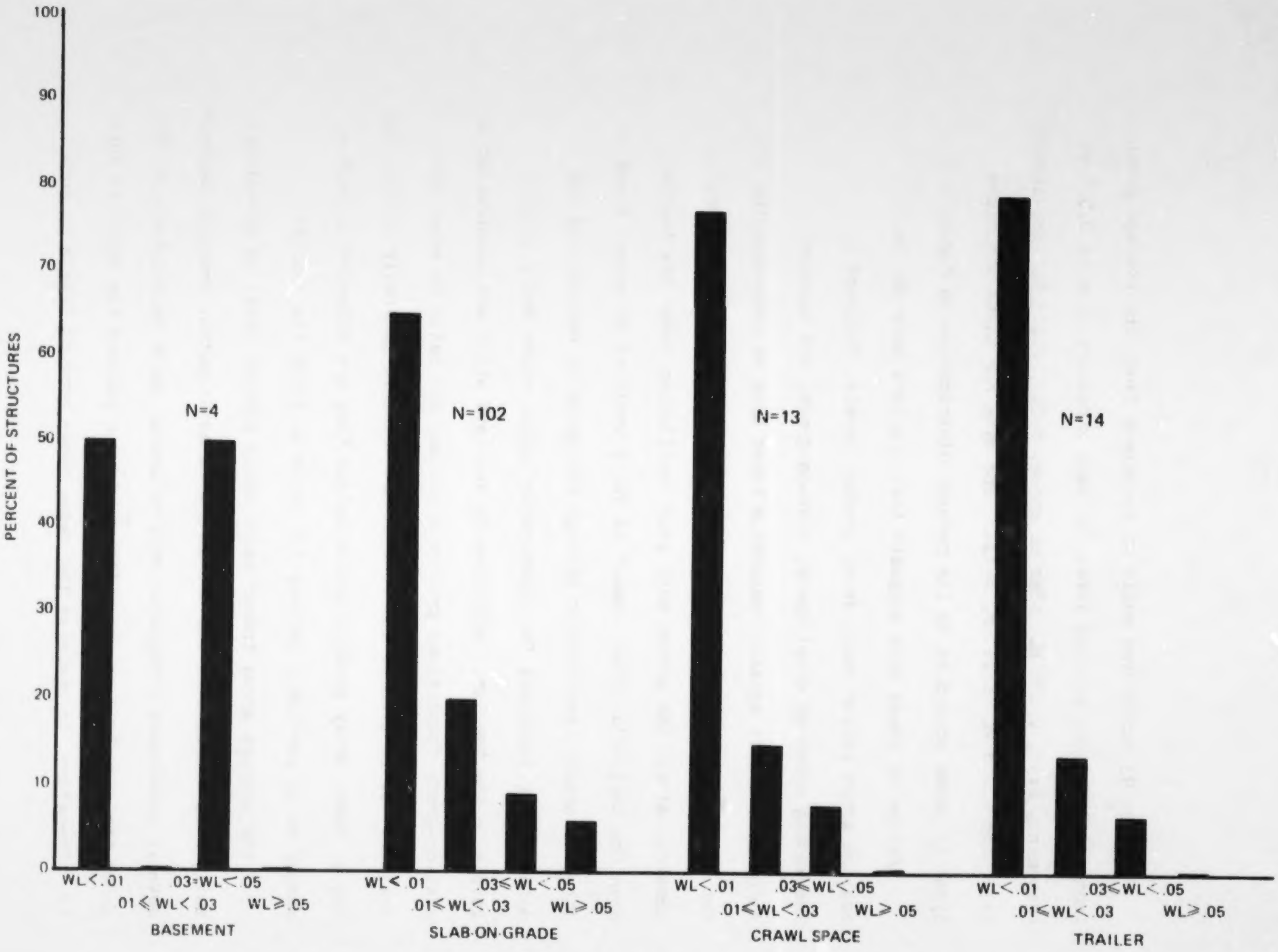

Figure D.4 PERCENT DISTRIBUTION OF TLD AIR SAMPLING MEASUREMENTS BY STRUCTURE TYPE AND GROSS WORKING LEVEL RANGE

Of the 93 structures built on reclaimed land, the average gross indoor radon decay product level for each structure type is 0.026 WL (basement, N=3), 0.018 WL (slab on grade, N=70), 0.013 WL (crawlspace, N=7), and 0.008 WL (trailer, N=13). The data for these structure types is shown according to its percent distribution in Figure D.5.

Review of these data suggests that trailers have the least average gross indoor radon decay product levels, followed in increasing order by crawl space, slab-on-grade, and basement structures. This appears reasonable based upon an understanding of the characteristics of each structure type. Trailers are generally constructed off the ground with good ventilation under the trailer. When the trailer's "crawl space" is fully enclosed by cement block or other materials, ventilation through the space is reduced and the potential is increased for undesirable indoor radon decay product levels in the trailer. Additions to trailers which are constructed on slab-on-grade foundations provide a pathway for radon to enter the trailer. It is evident therefore, that trailers generally exhibit low indoor radon decay product levels unless they are situated in such a manner as to provide a pathway for radon to enter the trailer.

The average gross indoor radon decay product level in structures built with crawlspaces was not as low as anticipated, probably because several crawlspace structures were enclosed, which restricted air flow under the structure or otherwise provided a pathway for radon to enter it. Therefore, to minimize the radon decay product levels in such

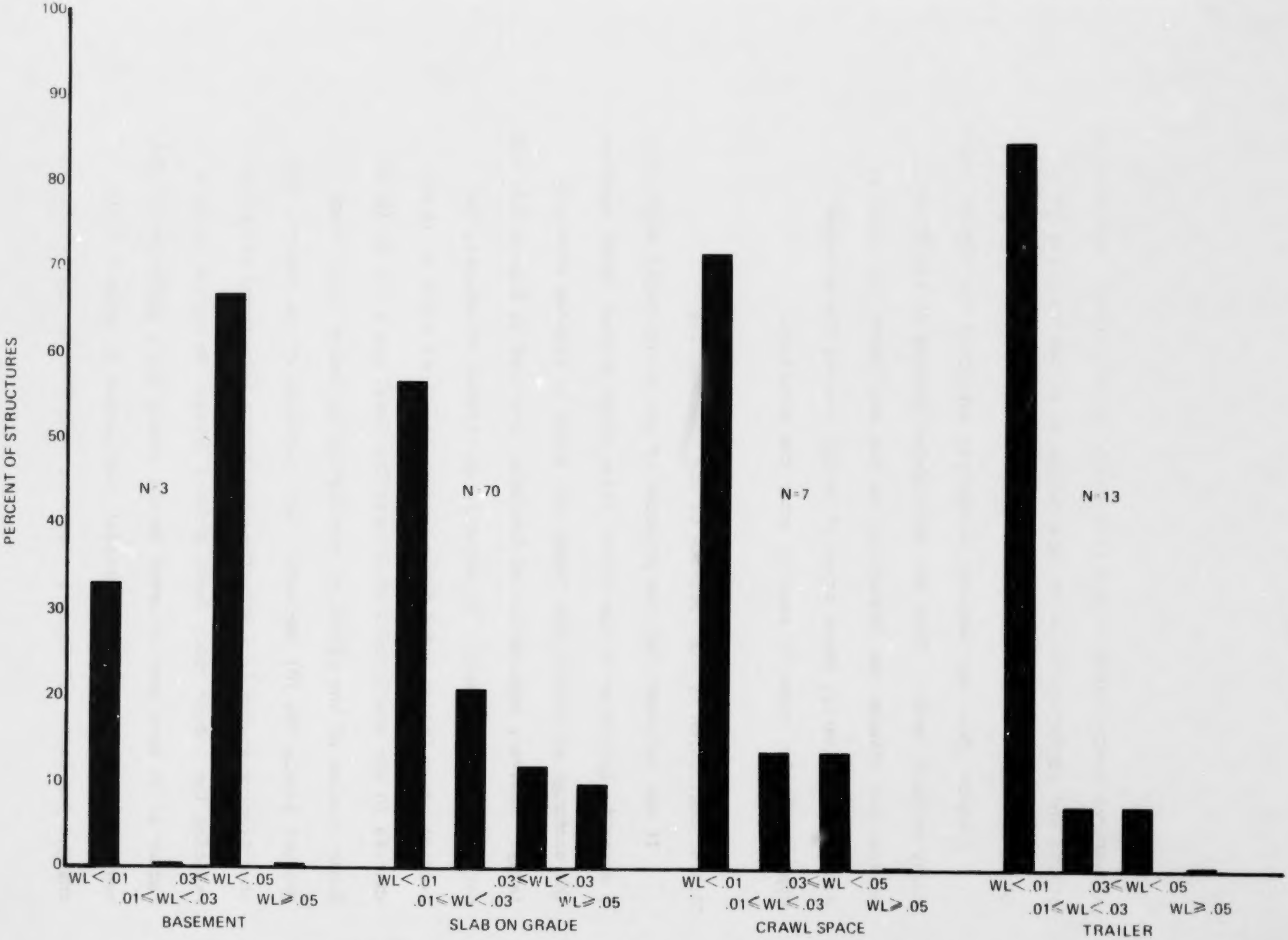

Figure D.5 PERCENT DISTRIBUTION OF TLD AIR SAMPLING MEASUREMENTS BY STRUCTURE TYPE AND GROSS WORKING LEVEL RANGE FOR RECLAIMED LAND

structures restrictions on air flow should be minimized. For example, piping and supports should be constructed so as not to allow for a radon pathway.

Slab-on-grade and basement structures exhibited the highest radon decay product levels. This was anticipated because of the direct interaction between the foundation and the soil where the radon is generated. Clearly, these types of design present the greatest opportunity for radon to readily enter the structure.

D.1.5 Evaluation by the Presence of Air Conditioning

It was believed that the presence of air conditioning might have a dramatic influence on the indoor radon decay product level because the exchange of outdoor and indoor air would be reduced substantially. However, examination of the data, provided in Figure D.6, did not confirm this theory. In non-air conditioned structures, the average gross indoor radon decay product level was 0.016 WL (N=47) whereas in air conditioned structures the level was 0.012 WL (N=86). Other studies of the effect of ventilation on indoor radon decay product levels (Un 78) indicated that operation of the central air conditioning system in a structure can have a pronounced effect on reducing the indoor radon decay product levels. Reduction up to a factor of 10 have been observed during steady state operation of the ventilation system versus a minimal ventilation of about 0.7 air changes per hour. It appears that this reduction is due to plateout

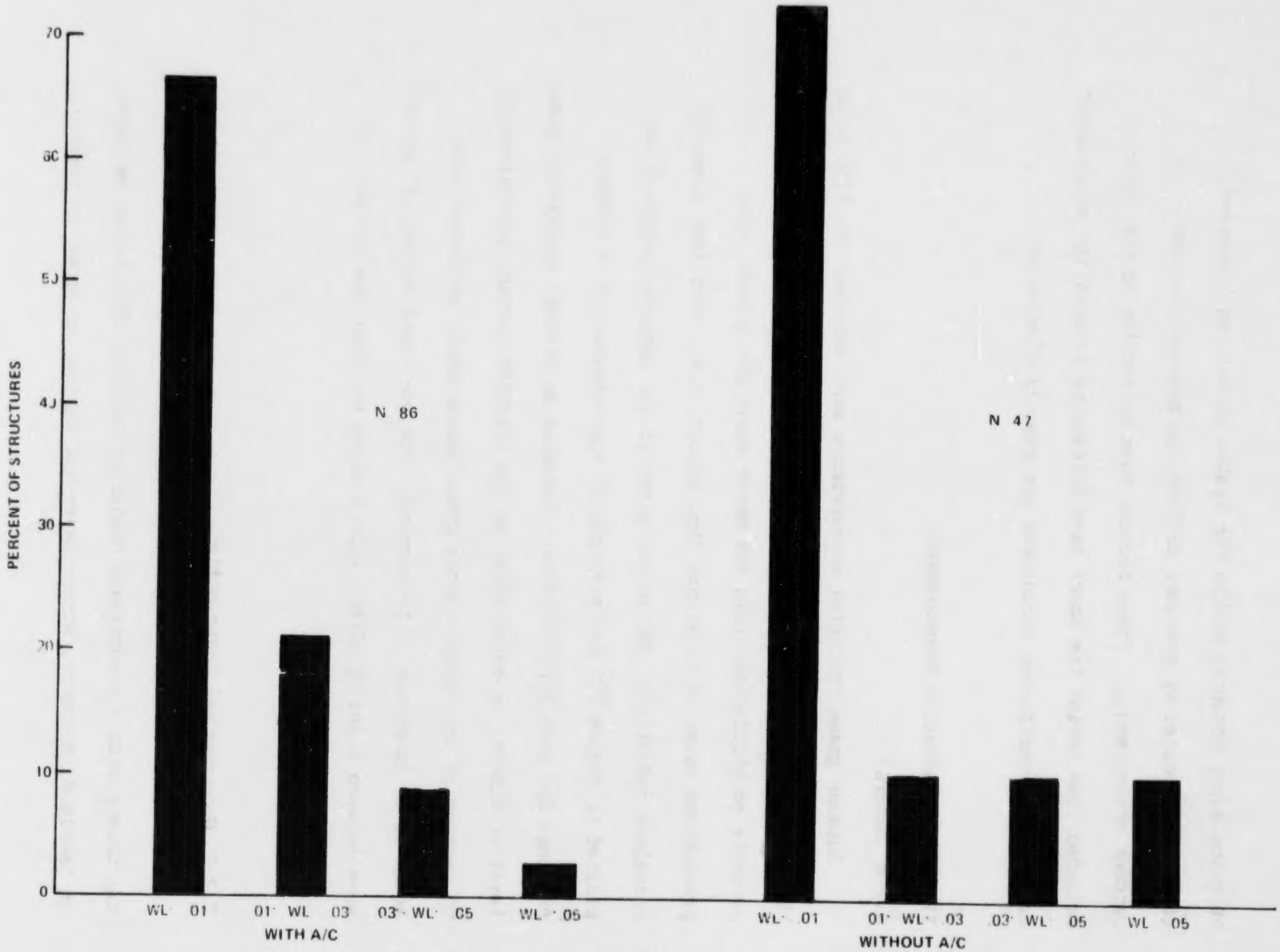

Figure D.6 PERCENT DISTRIBUTION OF TLD AIR SAMPLING MEASUREMENTS BY GROSS WORKING LEVEL RANGE

of radon decay products within the system as well as increased ventilation caused by pressure differences between the indoor and outdoor environments. These factors seem to combine so that over an extended time period the short term difference between air conditioned and non-air conditioned structures are greatly eliminated.

II. Gamma Radiation Measurements

D.2.1 General

Outdoor gamma radiation measurements were obtained for 1102 sites in Polk County. The gamma surveys were performed with a standard portable scintillometer held one meter above the ground, with precautions taken to eliminate "hot spots", i.e., localized areas of anomalous radiation. The values given in the appended printout and plotted in Figure D.7 are averages of approximately 8-10 outdoor readings for each surveyed site. Assuming an average background gamma level of 6μR/hr, as established by the EPA/DHRS survey, approximately 97 percent of the outdoor gross gamma measurements performed were equal to or in excess of background. For the total survey, 87 percent were between 6 and 15 μR/hr, with 9 sites or about one percent, in excess of 30 μR/hr.

D.2.2 Geographical Distribution

The gamma survey was performed in nineteen cities and towns in the County with a predominant number of surveys (853) being performed in Lakeland, Mulberry, Winter Haven and Bartow, as shown in Table D.7.

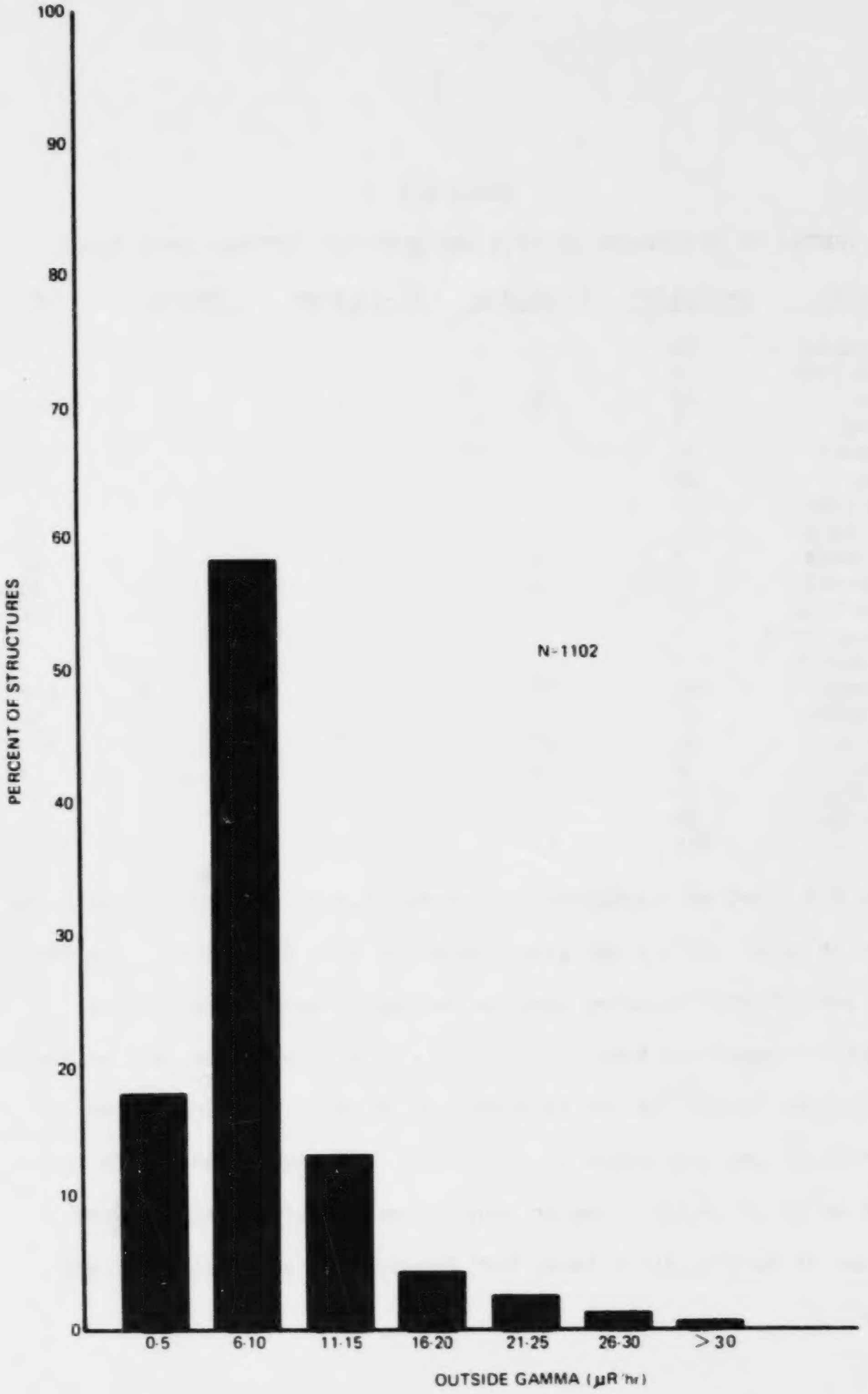

Figure D.7 **PERCENT DISTRIBUTION OF OUTSIDE GAMMA RADIATION MEASUREMENTS**

TABLE D.7

NUMBER OF STRUCTURES BY CITY AND SPECIFIC OUTDOOR GAMMA RANGE

City	0-10μR/hr	11-20μR/hr	21-30μR/hr	30μR/hr	N
Auburndale	15				15
Babson Park	1				1
Bartow	44	19	4		67
Bradley	4	1			5
Davenport	25				25
Dundee	22	1			23
Eagle Lake	1				1
Eaton Park	18	3	2		23
Fort Meade	9	10	4		23
Frostproof	23	7			30
Haines City	37				37
Highland City	1				1
Lake Alfred	1				1
Lakeland	466	127	21	2	616
Lake Wales	35				35
Mulberry	41	47	10	3	101
Pierce	2	2	1		5
Polk City	24				24
Winter Haven	69				69
TOTAL	838	217	42	5	1102

Figure D.8 provides a geographical representation of this data with the number of sites and average gamma range for each city noted. The "Pebble 55-70 percent BPL" boundary denotes the approximate extent of the phosphate mineralized zone. As the site data illustrates, all of the measurements except for one in excess of 10 μR/hr were located on mineralized land (reclaimed or otherwise). Average measurements in excess of 20 μR/hr (53 sites or about 5 percent of the sites) were obtained in Bartow, Eaton Park, Fort Meade, Lakeland, Mulberry, and Pierce.

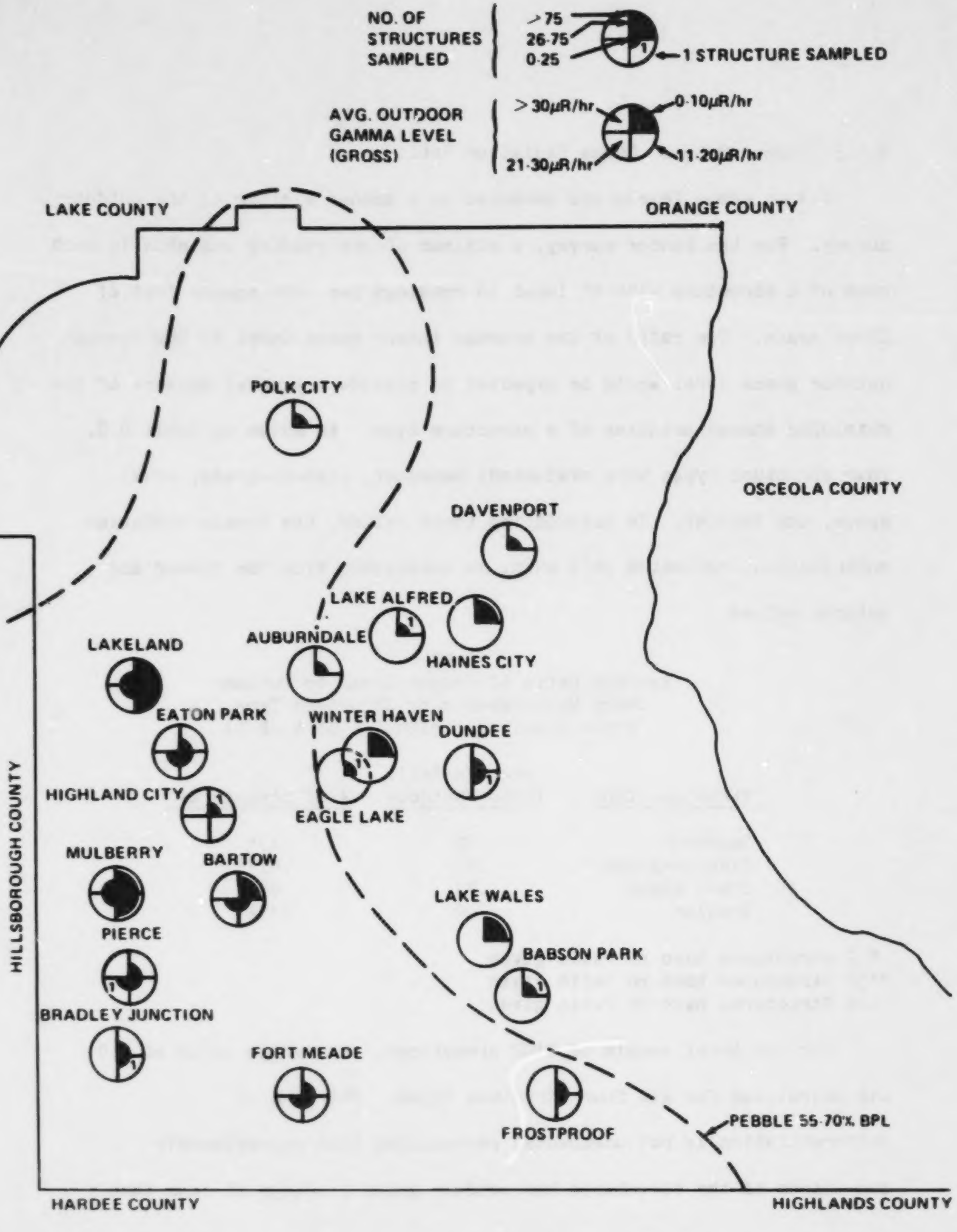
NO. OF STRUCTURES SAMPLED
>75
26-75
0-25
1
1 STRUCTURE SAMPLED
AVG. OUTDOOR GAMMA LEVEL (GROSS)
>30μR/hr
0-10μR/hr
21-30μR/hr
11-20μR/hr
LAKE COUNTY
ORANGE COUNTY
POLK CITY
OSCEOLA COUNTY
DAVENPORT
LAKE ALFRED
AUBURNDALE
HAINES CITY
LAKELAND
EATON PARK
WINTER HAVEN
DUNDEE
HIGHLAND CITY
EAGLE LAKE
HILLSBOROUGH COUNTY
MULBERRY
BARTOW
LAKE WALES
PIERCE
BABSON PARK
BRADLEY JUNCTION
FORT MEADE
FROSTPROOF
PEBBLE 55-70% BPL
HARDEE COUNTY
HIGHLANDS COUNTY

Figure D.8 **AVG OUTDOOR GAMMA RADIATION DISTRIBUTION (GROSS) FOR POLK COUNTY, FLORIDA (N=1102)**

D.2.3 Indoor/Outdoor Gamma Radiation Ratio

Indoor gamma levels are measured in a manner similar to the outdoor survey. For the indoor survey, a minimum of one reading was made in each room of a structure with at least 10 readings per 1000 square feet of floor space. The ratio of the average indoor gamma level to the average outdoor gamma level would be expected to provide a general measure of the shielding characteristics of a structure type. As shown in Table D.8, four structure types were evaluated: basement, slab-on-grade, crawl space, and trailer. In calculating these ratios, the cosmic radiation contribution, estimated at 4 μR/h, is subtracted from the indoor and outdoor values.

TABLE D.8
Average Ratio of Indoor Gamma to Outdoor
Gamma Measurements by Structure Type
(minus cosmic contribution of 4 μR/h)

Structure Type	Average Ratio Indoor/Outdoor	# of Structures
Basement	.79	13*
Slab-on-grade	.83	765**
Crawl Space	.91	60+
Trailer	.90	215+

* 2 structures have no ratio given
**32 Structures have no ratio given
+15 Structures have no ratio given

For the total sample of 1102 structures, an average ratio of 0.9 was calculated for all four structure types. The lack of differentiation is not unexpected recognizing that approximately two-thirds of the structures had outdoor gamma readings of less than

10 μR/hr. These readings roughly approximate the observed background level of 6μR/hr, thereby leading to a high "noise" level by which a representative relationship between outdoor to indoor gamma is masked. This effect is supported by ratio calculations for observations equal to or greater than 10 and 15 μR/hr, respectively. As shown in Tables D.9 and D.10, the average ratio for all structure types is less for these observations. The ratio for basements and slabs is as much as a factor of two less than the total sample, which corresponds to an attenuation factor of 0.4 for a four inch layer of concrete (6 percent porosity). Accepting this premise, structures with underlying layers of concrete appear to be between two and three times as effective in reducing gamma flux than those that do not (i.e., crawl space and trailers, with a underlying layer of air and flooring). In summary, inside gamma was greater than outside gamma for 80 sites (7 percent), less than outside gamma for 606 sites (55 percent), and about equal for 404 sites (38 percent).

TABLE D.9

A. Average Ratio of Indoor Gamma to Outdoor Gamma Measurements by Structure Type for Observations equal to or greater than 10 R/hr (Basement (B), Slab (S), Crawlspace (C), Trailer (T)) (minus cosmic contribution of 4 R/h)

Structure Type	Average Indoor/Outdoor	# of Structures
B	0.44	4
S	0.53	257
C	0.77	28
T	0.80	52

B. Statistical Comparison of Average Gamma Ratios

Type	N	Avg Ratio	F-test Value	PR F*
B	4	0.44		
S	257	0.53	28.47	0.0001
C	28	0.77		
T	52	0.80		
S	257	0.53		
C	28	0.77	42.19	0.0001
T	52	0.80		
C	28	0.77	0.32	0.5727
T	52	0.80		
S	257	0.53	28.40	0.0001
C	28	0.77		

*Probability that the sample distributions are a product of random variability

TABLE D.10

A. Average Ratio of Indoor Gamma to Outdoor Gamma Measurements by Structure Type for Observations Equal to or Greater than 15 μR/hr (Basement (B), Slab (S), Crawl Space (C), Trailer (T)) (minus cosmic contribution of 4 μR/h)

Structure Type	Average Indoor/Outdoor	# of Structures
B	0.42	1
S	0.41	87
C	0.81	13
T	0.79	22

B. Statistical Intercomparison of Average Gamma Ratios

Type	N	Avg. Ratio	F-test Value	PR > F*
B	1	0.42		
S	87	0.41	45.50	.0001
C	13	0.81		
T	22	0.79		
S	87	0.41		
C	13	0.81	67.14	.0001
T	22	0.79		
C	13	0.81	0.03	.0001
T	22	0.79		
S	87	.41	54.90	.0001
C	13	.81		

*Probability that the sample distributions are a product of random variability

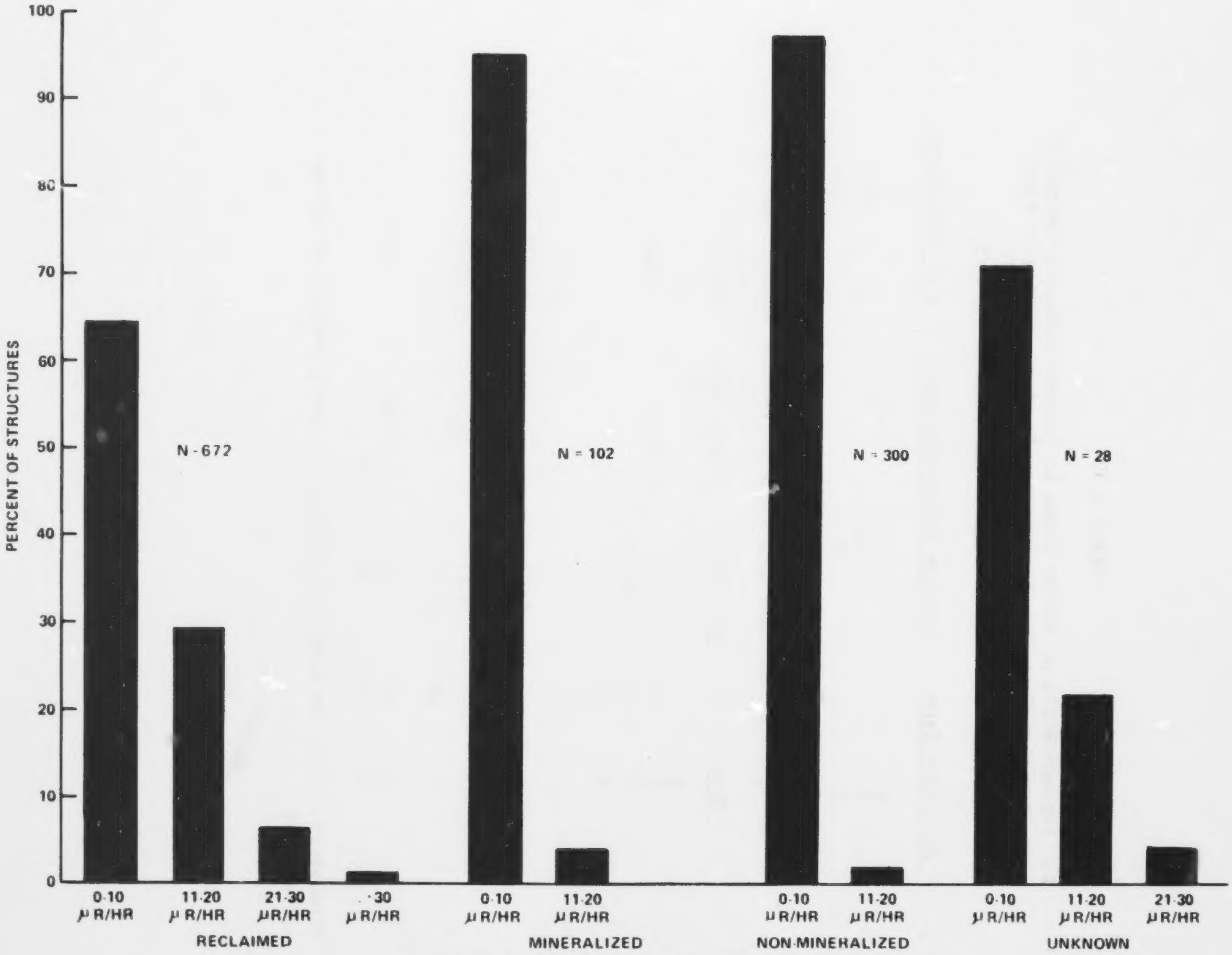

Figure D.9 PERCENT DISTRIBUTION OF GAMMA EXPOSURE RATE BY LAND CATEGORY*

*Ranges not shown indicate N=0

D.2.4 Evaluation by Land Category

As part of the overall survey, outdoor gamma measurements were evaluated according to the land category of the site. Four primary categories were delineated on the basis of the presence or absence of phosphate matrix, and past mining and reclamation: reclaimed mining sites, mineralized sites, non-mineralized sites, and sites of unknown designation. In Table D.11 and Figure D.9, a distribution of measurements in increasing increments of 10 μR/hr is given for these categories.

A statistical (F-test) intercomparison of the data shows a probable difference between the three distributions (excluding the "unknown" category) at the 99 percent confidence level. This evaluation, summarized in Table D.12, suggests that on the basis of the sample data collected, these land categories have statistically unique gamma distributions associated with them.

TABLE D.11

Outdoor Gamma Survey Distribution of all structure sites by Land Category

	Range of Outdoor Gamma Measurement (μ R/hr)					
Use	N	0-10	11-20	21-30	> 30	Average
Reclaimed (R)	672	429	198	40	5	10.7
Mineralized (M)	102	97	5	0	0	7.2
Non-Mineralized (N)	300	292	8	0	0	5.6
Unknown (U)	28	20	7	1	0	-
TOTAL	1102	838	218	41	5	-

TABLE D.12

Statistical Comparison of Gamma Survey
Distribution for Selected Land Categories
(reclaimed (R) mineralized (M) non-mineralized (N))

Use	N	Avg Gamma	F test-Value	PR > F*
M	102	7.0		
N	300	5.8	39.64	0.0001
R	672	10.7		
M	102	7.0		
R	672	10.7	244.34	0.0001
N	300	5.8		
R	672	10.7	139.26	0.0001
M	102	7.0		
N	300	5.8	55.35	0.0001

*Probability that the sample distributions are a product of random variability

D.2.5 Evaluation by Structure Type and Land Category

Indoor gamma exposure was evaluated on the basis of both structure type and land category. As a preponderance of structures (677) in the survey are located on land identified as being reclaimed, the gamma measurement distribution for the four structural categories were taken for structures so located, as provided in Figure D.10.

III. Track-Etch Measurements

Radon decay product levels were estimated in 153 structures with track-etch film. In this pilot study, the film was placed in a

TABLE D.12

Statistical Comparison of Gamma Survey
Distribution for Selected Land Categories
(reclaimed (R) mineralized (M) non-mineralized (N))

Use	N	Avg Gamma	F test-Value	PR > F*
M	102	7.0		
N	300	5.8	39.64	0.0001
R	672	10.7		
M	102	7.0		
R	672	10.7	244.34	0.0001
N	300	5.8		
R	672	10.7	139.26	0.0001
M	102	7.0		
N	300	5.8	55.35	0.0001

*Probability that the sample distributions are a product of random variability

D.2.5 Evaluation by Structure Type and Land Category

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III. Track-Etch Measurements

Radon decay product levels were estimated in 153 structures with track-etch film. In this pilot study, the film was placed in a

166

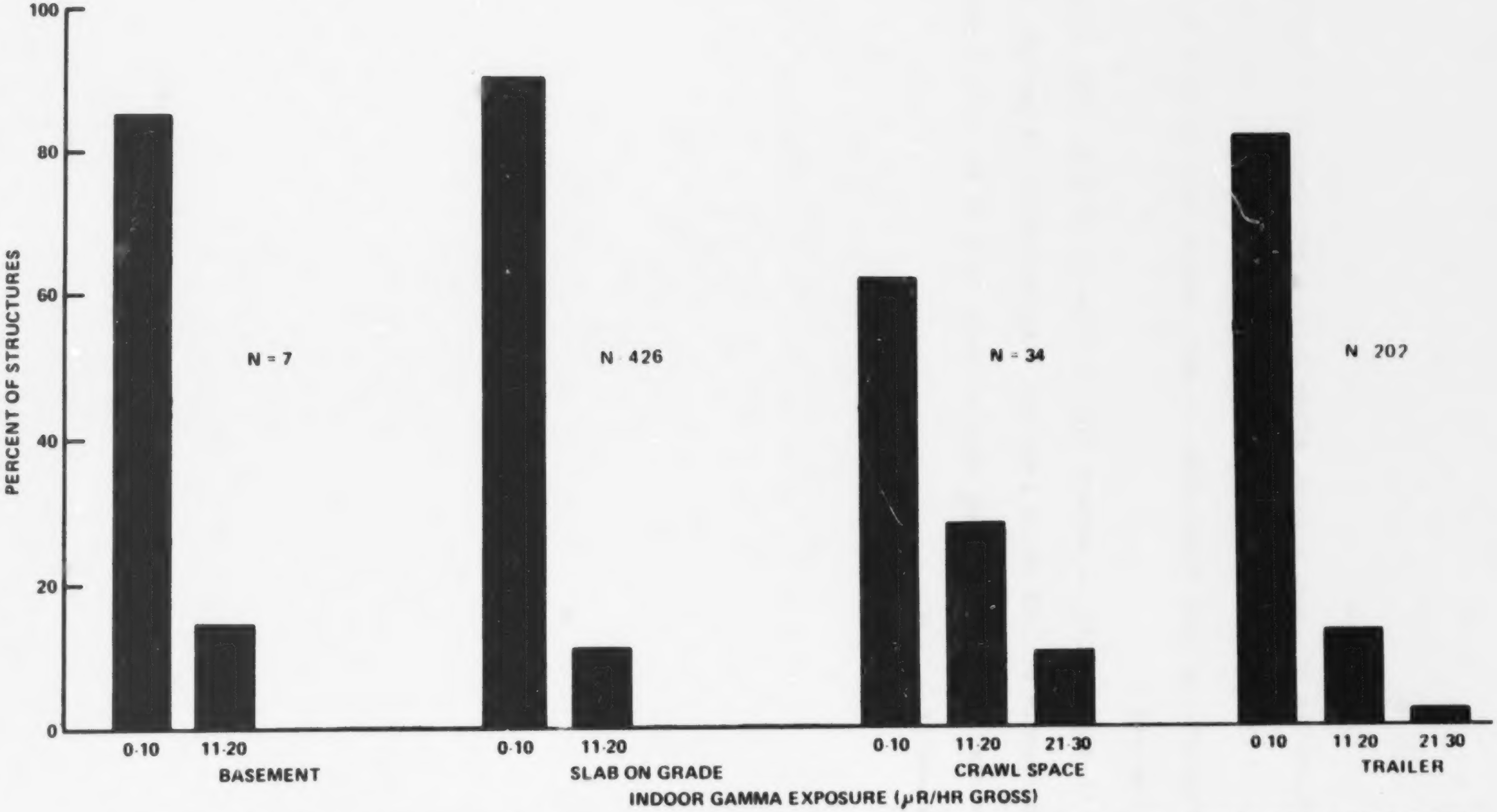

Figure D.10 PERCENT DISTRIBUTION FOR INDOOR GAMMA EXPOSURE RATE BY STRUCTURE TYPE FOR RECLAIMED LAND*

* RANGES NOT SHOWN INDICATE N=0

structure for at least a year, after which a representative count was taken of the "etches" caused by alpha energy deposition. This count is translatable into radon decay product levels (see Appendix B of this report).

In Figure D.11, a percent distribution of working level estimates in increments of .006 WL is provided. Approximately 70 percent of these measurements were less than or equal to 0.03 WL, with 7 percent in excess of 0.09 WL.

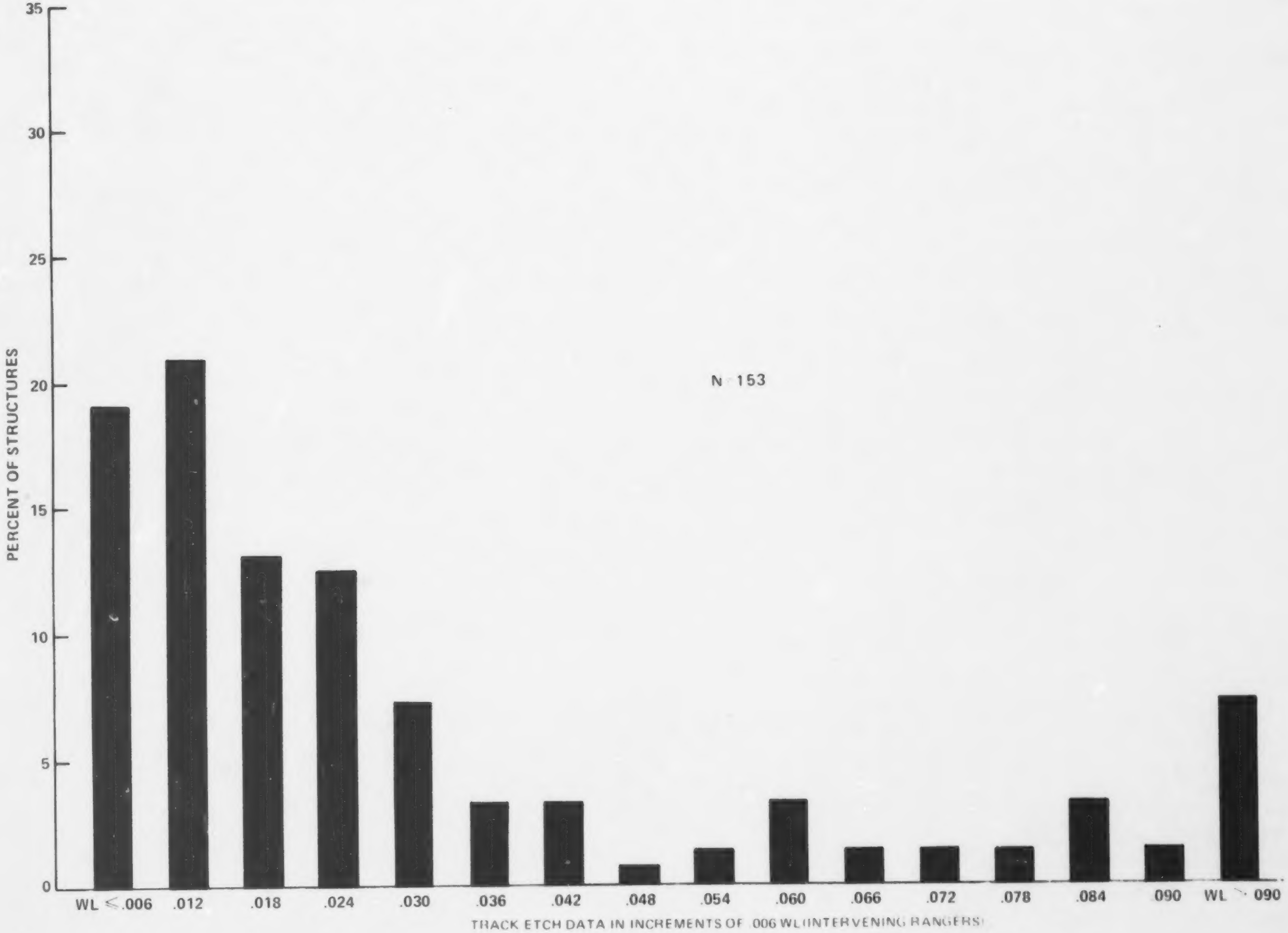

Figure D.11 PERCENT DISTRIBUTION OF EPA TRACK-ETCH DATA BY GROSS WORKING LEVEL RANGE

ANNEX

ANNEX KEY

"CLASS" CLASSIFICATION	"TYPE" TYPE STRUCTURE	"LEVELS" FLOOR LEVEL	"MATRIAL" MATERIAL	"A-C" AIR CONDITIONING
0. Vacant Lot	1. Basement	0. Unknown	0. Unknown	0. Unknown
1. Residence Single Family	2. Slab-on-grade	1. One floor	1. Masonry	1. Yes
2. Multiple (4 families)	3. Crawl space	2. Two floors	2. Non-masonry	2. No
	4. Trailer			3. Yes, never used
3. Apartment (Gt 4)	5. Unknown			4. Central always
4. Motel, hotel				5. Central seasonally
5. Single business				6. Central occasionally
6. Multiple business				7. Window recirculating always
7. School				8. Window recirculating seasonally
8. Church				9. Window recirculating occasionally
9. Other				A. Window makeup always
				B. Window makeup seasonally
				C. Window makeup occasionally

"AP-Mean": Air Pump Mean Working Level (WL)
"TE-Mean": Track Etch Mean Working Level (WL)
"GF-Gamma": Mean Indoor Ground Floor Gamma Exposure Rate (μR/hr)
"Out-Gamma": Mean Outdoor Gamma Exposure Rate (μR/hr)
"USE": "R"-Reclaimed, "M"-Mineralized, "N"-Non-mineralized, "U"-Unknown Land Use

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                         AIR PUMP AND TRACK ETCH AVERAGES ANC ALL LOCATION DATA                                    1
LCCATION  AP_MEAN  TE_MEAN  GF_GAMMA  OUT_GAMA  USE  CLASS  TYPE  LEVELS  MATRIAL  A_C  CITYNAME

 70050    0.0075   C.0226      12        10      R      9     2      1       1      5   LAKELAND
 70051    C.0173   C.01C2       9        11      R      9     2      1       1      5   EATON PARK
 70052             0.0083       8        12      R      1     2      1       1      6   LAKELAND
 70053             C.0209       6         7      R      1     2      1       1      6   LAKELAND
 70054             0.0091       4        10      R      1     2      1       1      6   EATON PARK
 70055             C.0096      10        11      R      1     2      1       1      6   LAKELAND
 70056                          7        15      R      1     2      1       1      0   LAKELAND
 70057             C.0151       5        12      R      1     2      1       1      5   LAKELAND
 70058             C.0089       7        12      R      1     2      1       1      6   LAKELAND
 70059             C.0089       5         9      R      1     2      1       1      6   LAKELAND
 70060             C.0223       6        11      R      1     2      1       1      6   LAKELAND
 70061             0.0152       6        14      R      1     2      1       1      5   LAKELAND
 70062             C.0086       8        13      R      1     2      2       1      6   LAKELAND
 70063             C.0069       8        12      R      1     2      1       1      6   LAKELAND
 70C64             0.0202       7        11      R      1     2      1       1      6   LAKELAND
 70065             0.0340       7        10      R      1     2      2       1      5   LAKELAND
 70066             C.0147       7         9      R      1     2      1       1      6   LAKELAND
 70C67             0.0047       5        10      R      1     2      1       1      6   LAKELAND
 70C68             C.0179       7        11      R      1     2      1       1      6   LAKELAND
 70069             0.0316       8         8      R      1     2      1       1      6   EATON PARK
 70C70             C.0082       4        12      R      1     2      1       1      6   EATON PARK
 70C71             C.0042       4         9      R      1     2      1       1      6   EATON PARK
 70072             0.0183       8         8      R      1     2      1       1      5   EATON PARK
 70C73             0.0040       7         8      R      1     2      1       1      6   EATON PARK
 70074                          5         8      R      1     2      1       1      6   LAKELAND
 70075             C.1248      18        25      R      1     2      1       1      6   BARTOW
 70C76    0.0626   0.0790      16        26      R      1     2      1       1      6   BARTOW
 70C77             C.0248      10        14      R      1     2      1       1      6   BARTOW
 70C78             0.0405      15        11      R      1     2      1       1      6   BARTOW
 70C79    0.C599   C.0619      10        12      R      1     2      1       7      6   BARTOW
 70080             0.0415      17        16      R      1     2      1       1      0   BARTOW
 7CC81             C.0029       9         7      R      1     3      1       2      2   BARTOW
 7CC82             0.0251      20         9      R      1     3      2       2      2   FT MEADE
 7CC83                                    3      R      1     3      1       2      2   FT MEADE
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                        AIR PUMP AND TRACK ETCH AVERAGES AND ALL LOCATION DATA                                   2
LOCATION  AP_MEAN  TE_MEAN  GF_GAMMA  CUT_GAMA  USE  CLASS  TYPE  LEVELS  MATRIAL  A_C  CITYNAME

 70084    0.0176   0.0012      27        29      U     1     3      1        2      2   FT MEADE
 70085                         15        23      R     1     3      1        2      0   FT MEADE
 70086             0.0017      15        16      R     1     3      1        2      2   FT MEADE
 70087             0.0068      28        29      R     1     3      1        3      6   FT MEADE
 70088             0.0037       7        17      R     1     2      1        1      2   BARTOW
 70089             0.0227      14        18      R     1     2      1        1      2   BARTOW
 70090             0.0089       9        14      R     1     2      1        1      2   BARTOW
 70091             0.0208      15        16      R     1     2      1        1      2   BARTOW
 70092             0.0012       8         8      R     1     1      1        1      1   MULBERRY
 70093             0.0107       8         5      R     1     2      1        1      6   MULBERRY
 70094    0.0322   0.0468      12        23      R     1     1      1        1      6   LAKELAND
 70095             0.0598      16        28      R     1     2      1        1      6   LAKELAND
 70096             0.0170      14        24      R     1     2      1        1      6   LAKELAND
 70097             0.0217      15        24      R     1     2      1        1      6   LAKELAND
 70098    0.1045               20        25      R     1     2                       0   LAKELAND
 70099             0.0013       3         8      U     1     2      1        1      6   AUBURNDALE
 70100             0.0187       5        13      U     1     2      1        1      6   LAKELAND
 70101             0.0057      12        20      U     1     2      1        1      6   LAKELAND
 70102             0.0250       7        15      U     1     2      1        1      5   LAKELAND
 70103             0.0157       9         7      R     1     2      1        1      6   LAKELAND
 70104                          9        14      R     1     2      1        1      2   LAKELAND
 70105    0.0385   0.0186      10        21      R     9     2      1        1      6   LAKELAND
 70106             0.0939      15        30      R     1     2      1        1      6   LAKELAND
 70107    0.0673   0.0768      15        31      R     1     2      1        1      6   LAKELAND
 70108             0.0087      11        23      R     1     2      1        1      2   LAKELAND
 70109             0.0032      12        20      R     1     2      1        1      6   LAKELAND
 70110    0.0721   0.0839      12        22      R     1     2      1        1      6   LAKELAND
 70111             0.0082      16        17      R     1     2      1        1      6   MULBERRY
 70112    0.0036   0.0099       9        23      R     9     2      1        1      0   MULBERRY
 70113             0.0252      19        33      R     1     2      1        1      6   MULBERRY
 70114             0.0210      16        15      R     1     3      1        3      6   MULBERRY
 70115             0.0048      16        15      R     1     3      1        1      2   PIERCE
 70116             0.0155       5         9      R     1     2      1        1      2   BRADLEY JUNCTION
 70117             0.0900      11        23      R     8     2      1        1      6   PIERCE
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                      AIR PUMP AND TRACK ETCH AVERAGES AND ALL LOCATION DATA

LOCATION  AP_MEAN  TE_MEAN  GF_GAMMA  OUT_GAMA  USE  CLASS  TYPE  LEVELS  MATRIAL  A_C  CITYNAME

 70118    0.0106   0.0050       7        8.0     R     1      2      0       0      2   PIERCE
 70119             0.0565      12       17.0     R     1      2      1       1      6   LAKELAND
 70120             0.0702      14       15.0     R     1      2      1       1      6   LAKELAND
 70121             0.0277       8       15.0     R     9      2      1       1      5   LAKELAND
 70122             0.0162       6       13.0     R     1      2      1       1      5   MULBERRY
 70123             0.0154      14       20.0     R     1      2      1       1      6   LAKELAND
 70124             0.0120       6       16.0     R     1      2      1       1      6   LAKELAND
 70125                          6        9.0     R     1      3      1       2      2   LAKELAND
 70126             0.0154       5        7.0     R     1      3      1       2      2   LAKELAND
 70127             0.0053       7       10.0     R     1      2      1       1      6   LAKELAND
 70128             0.0057       6       10.0     R     1      1      1       1      6   LAKELAND
 70129                         12       35.0     R     1      2      1       2      0   LAKELAND
 70130             0.0096      14       17.0     R     1      2      1       1      6   LAKELAND
 70131             0.0297      15       18.0     R     1      2      1       1      6   LAKELAND
 70132             0.0166      13       15.0     R     1      2      1       2      6   LAKELAND
 70134    0.0013   0.0069       3        6.0     N     1      2      1       1      5   WINTER HAVEN
 70135    0.0008   0.0089       3        6.0     N     1      2      1       1      2   LAKE ALFRED
 70136    0.0013   0.0026       4        7.0     N     1      1      2       1      2   EAGLE LAKE
 70137    0.0009   0.0143       4        6.0     N     1      2      1       1      6   WINTER HAVEN
 70138             0.0027       3        5.5     N     1      2      2       1      6   WINTER HAVEN
 70139             0.0250       3        6.0     N     1      3      1       2      5   HAINES CITY
 70140             0.0141       3        6.0     N     1      2      1       1      6   LAKE WALES
 70141             0.0089       3        6.0     N     1      1      1       1      6   BABSON PARK
 70146                          3        3.0     N     1      2      1       1      2   AUBURNDALE
 70147                          3        4.0     N     1      3      1       1      0   AUBURNDALE
 70148             0.0102       3        8.0     N     1      3      1       1      6   AUBURNDALE
 70149             0.0034       4        4.0     N     1      3      1       2      2   POLK CITY
 70150             0.0088       7        7.0     U     9      1      1       1      5   BARTOW
 70151             0.0052      10        7.0     M     1      3      1       2      6   FT MEADE
 70152             0.0198       6        6.0     N     1      2      1       1      6   FT MEADE
 70166             0.0666       9       16.0     M     1      2      1       1      6   LAKELAND
 70167             0.1256      18       13.0     M     1      2      1       1      6   LAKELAND
 70168                         15       17.0     M     1      3      1       3      0   LAKELAND
 70169    0.0252   0.0203      10       11.0     M     9      2      1       1      5   MULBERRY
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AIR PUMP AND TRACK ETCH AVERAGES AND ALL LOCATION DATA

LOCATION	AP_MEAN	TE_MEAN	GF_GAMMA	CUT_GAMA	USE	CLASS	TYPE	LEVELS	MATRIAL	A_C	CITYNAME
70170	0.0065	0.0192	7	5	M	1	2	1	1	6	MULBERRY
70171		0.0604	9	9	M	1	2	1	1	6	BRADLEY JUNCTION
70172	0.0329	0.0288	13	13	M	9	2	1	1	5	BRADLEY JUNCTION
70173		0.0135	6	8	M	1	2	1	1	6	HIGHLAND CITY
70174		0.0338	6	10	N	1	3	2	2	6	BARTOW
70175	0.0022	0.0080	4	4	N	1	3	1	1	2	LAKELAND
70176	0.0027		4	5	N	1	3			0	LAKELAND
70177			3	4	N	1	2	1	1	0	LAKELAND
70178		0.0200	4	5	N	1	2	1	1	6	LAKELAND
70179			4	4	N	1	2	1	1	0	LAKELAND
70180	0.0033	0.0073	4	4	N	9	2	1	1	5	LAKELAND
70181		0.0285	3	6	N	1	2	1	1	6	LAKELAND
70182		0.0075	3	6	N	1	2	1	1	5	LAKELAND
70183		0.0135	3	6	N	1	3	1	2	2	LAKELAND
70184		0.0143		9	N	9	2	2	1	2	LAKELAND
70185		0.0180	3	6	N	1	2	1	1	6	LAKELAND
70186		0.0060	3	6	N	1	3	1	2	2	LAKELAND
70187		0.0128	3	6	N	1	2	1	1	2	LAKELAND
70188		0.0075	3	6	N	1	3	1	2	6	LAKELAND
70189		0.0038	3	6	N	1	2	1	1	6	LAKELAND
70190		0.0035	3	6	N	1	3	1	2	2	LAKELAND
70191		0.0050	3	6	N	1	3	1	2	2	LAKELAND
70192		0.0027	4	4	N	1	2	1	1	2	LAKELAND
70300		0.0501	4	10	R	1	2	1	1	1	LAKELAND
70301		0.0150	4	11	R	1	2	1	1	1	LAKELAND
70302		0.0201	4	12	R	1	2	2	1	1	LAKELAND
70303		0.0506	5	20	R	1	2	1	1	5	LAKELAND
70304		0.0206	9	14	R	1	2	1	1	4	LAKELAND
70305		0.0313	6	10	R	1	2	1	1	5	LAKELAND
70306		0.0207	7	13	R	1	2	1	1	5	LAKELAND
70307		0.0244	5	15	R	1	2	1	1	5	LAKELAND
70308		0.0557	9	17	R	9	2	1	1	1	LAKELAND
70309		0.0410	7	15	R	1	2	1	1	5	LAKELAND
70310		0.0307	4	19	R	1	2	1	1	4	LAKELAND

AIR PUMP AND TRACK ETCH AVERAGES AND ALL LOCATION DATA

LOCATION	AP_MEAN	TE_MEAN	GF_GAMMA	OUT_GAMA	USE	CLASS	TYPE	LEVELS	MATRIAL	A_C	CITYNAME
70311		0.0296	6	14	R	1	2	1	1	5	LAKELAND
70312		0.0387	7	15	R	1	2	1	1	5	LAKELAND
70313		0.0232	7	16	R	1	2	1	1	6	LAKELAND
70314		0.0118	6	20	R	1	2	1	1	3	LAKELAND
70315		0.0795	8	17	R	1	2	1	1	4	LAKELAND
70316		0.1311	10	30	R	1	2	1	1	1	LAKELAND
70317		0.0554	8	18	R	1	2	1	1	5	LAKELAND
70318		0.0778	7	13	R	1	2	1	1	5	LAKELAND
70319		0.1373	5	13	R	1	2	1	1	4	LAKELAND
70320		0.0915	6	30	R	1	2	1	1	5	LAKELAND
70321			5	8	R	1	2	1	1	1	BARTOW
70322			8	15	R	1	2	1	1	1	BARTOW
70323		0.0872	10	25	R	1	2	1	1	1	BARTOW
70324		0.0879	8	25	R	1	2	1	1	1	BARTOW
70325		0.0567	7	16	R	1	2	1	1	1	BARTOW
70326		0.0049	4	6	R	1	3	1	1	1	BRADLEY JUNCTION
70327		0.0047	3	5	R	1	2	1	1	2	BRADLEY JUNCTION
70330		0.0078	3	4	R	1	3	1	2	2	BARTOW
70331		0.0074	4	13	R	5	2	1	1	1	BARTOW
70332		0.0060	8	11	R	1	2	1	1	1	BARTOW
70333		0.0053	8	14	R	1	2	1	1	1	BARTOW
70334		0.0077	6	9	R	1	2	1	1	1	BARTOW
70335		0.0550		14	R	1	2	1	1	1	BARTOW
70336		0.0026		6	R	1	3	1	2	1	BARTOW
70337		0.0072	6	9	R	1	2	1	1	1	BARTOW
70338		0.0226	15	12	R	1	2	1	1	1	BARTOW
70339		0.0096		13	R	1	2	1	1	1	PIERCE
70350		0.0830	5	7	R	1	2	1	1	1	LAKELAND
70351			7	6	R	1	2	1	2	1	LAKELAND
70352			13	28	R	1	2	1	1	6	LAKELAND
70353		0.0321	8	24	R	1	2	1	1	1	LAKELAND
70354		0.0456	8	16	R	1	2	1	1	1	LAKELAND
70355			6	21	R	1	2	0	0	6	LAKELAND
70356		0.0159	6	15	R	1	2	1	1	3	LAKELAND

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                      AIR PUMP AND TRACK ETCH AVERAGES AND ALL LOCATION DATA                                     5

LOCATION  AP_MEAN  TE_MEAN  GF_GAMMA  OUT_GAMA  USE  CLASS  TYPE  LEVELS  MATRIAL  A_C  CITYNAME

 70357                          8        22      R     1      2     1        1      6   LAKELAND
 70358             0.0926       6        15      R     1      2     1        1      1   LAKELAND
 70359             0.0837      11        25      R     1      2     1        1      1   LAKELAND
 70360                          9        20      R     1      2     1        1      6   LAKELAND
 70361                          7        23      R     1      2     1        1      1   LAKELAND
 70362                          6        19      R     1      2     1        1      6   LAKELAND
 70363                         10        11      R     1      2     1        1      1   LAKELAND
 70367                          6         6      R     1      2     1        1      1   AUBURNDALE
 70401                          7        11      R     1      4     1        2      1   LAKELAND
 70402                          8         9      R     1      4     1        2      1   LAKELAND
 70403                          8         9      R     1      4     1        2      1   LAKELAND
 70406    0.0076                6         7      R     1      4                      1   LAKELAND
 70407                          7         7      R     1      4     1        2      1   LAKELAND
 70408                          6         7      R     1      4     1        2      1   LAKELAND
 70409    0.0043                7         7      R     1      4                      1   LAKELAND
 70410                          8         8      R     1      4     1        2      1   LAKELAND
 70411                          9         9      R     1      4     1        2      1   LAKELAND
 70412                          9        10      R     1      4     1        2      1   LAKELAND
 70413                          9        11      R     1      4     1        2      1   LAKELAND
 70414                         10        10      R     1      4     1        2      1   LAKELAND
 70415                          7         7      R     1      4     1        2      1   LAKELAND
 70416    0.0035                7         7      R     1      4                      1   LAKELAND
 70417                          8         9      R     1      4     1        2      1   LAKELAND
 70418                          7         6      R     1      4     1        2      1   LAKELAND
 70419                          7         7      R     1      4     1        2      1   LAKELAND
 70420                          6         7      R     1      4     1        2      1   LAKELAND
 70421                          7         7      R     1      4     1        2      1   LAKELAND
 70422                         10        11      R     1      4     1        2      1   LAKELAND
 70423                         12        11      R     1      4     1        2      1   LAKELAND
 70424                          8         8      R     1      4     1        2      2   LAKELAND
 70425                          6         6      R     1      4     1        2      1   LAKELAND
 70426                          6         6      R     1      4     1        2      1   LAKELAND
 70427                          6         6      R     1      4     1        2      1   LAKELAND
 70428                          6         7      R     1      4     1        2      1   LAKELAND
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                    AIR PUMP AND TRACK ETCH AVERAGES AND ALL LOCATION DATA

LOCATION  AP_MEAN  TE_MEAN  GF_GAMMA  CUT_GAMA  USE  CLASS  TYPE  LEVELS  MATRIAL  A_C  CITYNAME

 70429                          6         6      U     1      4      1        2      1   LAKELAND
 70430                          6         6      U     1      4      1        2      1   LAKELAND
 70431                          5         5      U     1      4      1        2      1   LAKELAND
 70432                          5         5      U     1      4      1        2      1   LAKELAND
 70433                         10        11      R     1      4      1        2      1   LAKELAND
 70434                          9         9      R     1      4      1        2      1   LAKELAND
 70435                          7         8      R     1      4      1        2      1   LAKELAND
 70436                          9         9      R     1      4      1        2      1   LAKELAND
 70437                         10        11      R     1      4      1        2      1   LAKELAND
 70438                          6         6      R     1      4      1        2      1   LAKELAND
 70439                          7         7      R     1      4      1        2      1   LAKELAND
 70440                          7         6      R     1      4      1        2      1   LAKELAND
 70441                          7         8      R     1      4      1        2      1   LAKELAND
 70443                          7         7      R     1      4      1        2      2   LAKELAND
 70444                          7         7      R     1      4      1        2      1   LAKELAND
 70445                          6         6      R     1      4      1        2      1   LAKELAND
 70446    0.0046                7         7      R     1      4                      1   LAKELAND
 70447                          7         7      R     1      4      1        2      1   LAKELAND
 70448                          8         9      R     1      4      1        2      1   LAKELAND
 70449                         12        14      R     1      4      1        2      1   LAKELAND
 70450                         12        13      R     1      4      1        2      1   LAKELAND
 70451                         12        13      R     1      4      1        2      1   LAKELAND
 70452                          6         6      R     1      4      1        2      1   LAKELAND
 70453                          6         6      R     1      4      1        2      1   LAKELAND
 70454                          8         8      R     1      4      1        2      1   LAKELAND
 70455                          7         7      R     1      4      1        2      1   LAKELAND
 70456                          8         7      R     1      4      1        2      1   LAKELAND
 70457                          6         6      R     1      4      1        2      2   LAKELAND
 70458                          7         7      R     1      4      1        2      1   LAKELAND
 70459                          7         7      R     1      4      1        2      1   LAKELAND
 70460                          6         7      R     1      4      1        2      1   LAKELAND
 70461                          6         6      R     1      4      1        2      1   LAKELAND
 70462                          6         6      R     1      4      1        2      2   LAKELAND
 70463                          7         7      R     1      4      1        2      2   LAKELAND
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                    AIR PUMP AND TRACK ETCH AVERAGES AND ALL LOCATION DATA                         8

LOCATION  AP_MEAN  TE_MEAN  GF_GAMMA  CUT_GAMA  USE  CLASS  TYPE  LEVELS  MATRIAL  A_C  CITYNAME

  70464                         7         7      R     1      4      1        2      1   LAKELAND
  70465                         6         6      R     1      4      1        2      1   LAKELAND
  70466                         6         6      R     1      4      1        2      1   LAKELAND
  70467                         6         6      R     1      4      1        2      1   LAKELAND
  70468                         6         6      R     1      4      1        2      1   LAKELAND
  70469                         7         7      R     1      4      1        4      1   LAKELAND
  70470                         7         7      R     1      4      1        2      1   LAKELAND
  70471                         6         6      R     1      4      1        2      1   LAKELAND
  70472                         6         6      R     1      4      1        2      1   LAKELAND
  70473                         6         7      R     1      4      1        2      1   LAKELAND
  70474                         5         6      R     1      4      1        2      1   LAKELAND
  70475                         6         6      R     1      4      1        2      1   LAKELAND
  70476                         6         6      R     1      4      1        2      1   LAKELAND
  70477                         8         7      R     1      4      1        2      1   LAKELAND
  70478                        10         7      R     1      4      1        2      1   LAKELAND
  70479                         6         7      R     1      4      1        2      1   LAKELAND
  70480                         6         7      R     1      4      1        2      1   LAKELAND
  70481                         7         7      R     1      4      1        2      1   LAKELAND
  70482                         6         7      R     1      4      1        2      1   LAKELAND
  70483                         7         7      R     1      4      1        2      1   LAKELAND
  70484                         6         7      R     1      4      1        2      1   LAKELAND
  70485                         6         7      R     1      4      1        2      1   LAKELAND
  70486                         6         6      R     1      4      1        2      1   LAKELAND
  70487                         6         7      R     1      4      1        2      1   LAKELAND
  70488                         7         7      R     1      4      1        2      1   LAKELAND
  70489                         7         7      R     1      4      1        2      1   LAKELAND
  70490                         7         8      R     1      4      1        2      1   LAKELAND
  70491                         7         7      R     1      4      1        2      1   LAKELAND
  70492                         7         7      R     1      4      1        2      1   LAKELAND
  70493                         6         6      R     1      4      1        2      1   LAKELAND
  70494                         6         6      R     1      4      1        2      1   LAKELAND
  70495                         5         6      R     1      4      1        2      1   LAKELAND
  70496    0.0033               6         7      R     1      4                       1   LAKELAND
  70497                         6         7      R     1      4      1        2      1   LAKELAND
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                 AIR PUMP AND TRACK ETCH AVERAGES AND ALL LOCATION DATA

LOCATION  AP_MEAN  TE_MEAN  GF_GAMMA  CUT_GAMA  USE  CLASS  TYPE  LEVELS  MATRIAL  A_C  CITYNAME

 70498                          5         5      R     1     4      1        2      1   LAKELAND
 70499                          5         6      R     1     4      1        2      1   LAKELAND
 70500                          5         6      R     1     4      1        2      1   LAKELAND
 70501                          5         6      R     1     4      1        2      1   LAKELAND
 70502                          5         5      R     1     4      1        2      1   LAKELAND
 70503                          5         6      R     1     4      1        2      1   LAKELAND
 70504                          6         5      R     1     4      1        2      1   LAKELAND
 70505                          5         6      R     1     4      1        2      1   LAKELAND
 70506                          5         6      R     1     4      1        2      1   LAKELAND
 70507                          6         6      R     1     4      1        2      1   LAKELAND
 70508                          5         5      R     1     4      1        2      1   LAKELAND
 70509                          8         8      R     1     4      1        2      1   LAKELAND
 70510                          5         6      R     1     4      1        2      1   LAKELAND
 70511                          5         6      R     1     4      1        2      1   LAKELAND
 70512                          5         6      R     1     4      1        2      1   LAKELAND
 70513                          6         6      R     1     4      1        2      1   LAKELAND
 70514                          5         6      R     1     4      1        2      1   LAKELAND
 70515                          5         5      R     1     4      1        2      1   LAKELAND
 70516                          5         5      R     1     4      1        2      1   LAKELAND
 70517                          6         8      R     1     4      1        2      1   LAKELAND
 70518                          5         5      R     1     4      1        2      1   LAKELAND
 70519                          5         5      R     1     4      1        2      1   LAKELAND
 70520                          5         6      R     1     4      1        2      1   LAKELAND
 70521                          5         6      R     1     4      1        2      1   LAKELAND
 70522                          6         6      R     1     4      1        2      1   LAKELAND
 70523                          5         6      R     1     4      1        2      1   LAKELAND
 70524                          5         5      R     1     4      1        2      1   LAKELAND
 70525                         20         8      R     1     4      1        2      1   LAKELAND
 70526                          8         8      R     1     4      1        2      1   LAKELAND
 70527                          7         7      R     1     4      1        2      1   LAKELAND
 70528                          6         6      R     1     4      1        2      1   LAKELAND
 70529                          5         6      R     1     4      1        2      1   LAKELAND
 70530                          5         5      R     1     4      1        2      1   LAKELAND
 70531                          5         6      R     1     4      1        2      1   LAKELAND
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                  AIR PUMP AND TRACK ETCH AVERAGES AND ALL LOCATION DATA

LOCATION  AP_MEAN  TE_MEAN  OF_GAMMA  CUT_GAMA  USE  CLASS  TYPE  LEVELS  MATRIAL  A_C  CITYNAME

  70532                          7         8     R     1     4      1        2      1   LAKELAND
  70533                          7         6     R     1     2      1        1      1   LAKELAND
  70534                          7         8     R     1     2      1        1      1   LAKELAND
  70535                          7         8     R     1     2      1        1      1   LAKELAND
  70536                          6         7     R     1     2      1        1      1   LAKELAND
  70537                          7         8     R     3     2      2        1      1   LAKELAND
  70538                          7         8     R     3     2      1        1      1   LAKELAND
  70539   0.0384                13         8     R     1     2                      1   LAKELAND
  70540                          7        10     R     1     2      1        1      1   LAKELAND
  70541                          8        12     R     1     2      1        1      1   LAKELAND
  70542                          7        11     R     1     2      1        1      1   LAKELAND
  70543                          9        11     R     1     2      1        1      1   LAKELAND
  70544                          8         8     R     3     2      2        1      1   LAKELAND
  70545                          7        10     R     3     2      1        1      1   LAKELAND
  70546                          8        11     R     1     2      1        1      1   LAKELAND
  70547                          7         9     R     1     2      1        1      1   LAKELAND
  70548                          7         8     R     1     2      1        1      1   LAKELAND
  70549                          6         7     R     1     2      1        1      1   LAKELAND
  70550                          6         8     R     1     2      1        1      1   LAKELAND
  70551                          7         8     R     1     2      1        1      1   LAKELAND
  70552                          7         8     R     1     2      1        1      1   LAKELAND
  70553                          7         7     R     1     2      1        1      1   LAKELAND
  70554                         11        15     R     1     2      1        1      1   LAKELAND
  70555                          7         7     R     1     2      1        1      1   LAKELAND
  70556                          7         8     R     1     2      1        1      1   LAKELAND
  70557                          7         8     R     1     2      1        1      1   LAKELAND
  70558   0.0858                 7        10     R     1     2                      1   LAKELAND
  70559                          6         8     R     1     2      1        1      1   LAKELAND
  70560                          8         9     R     1     2      1        1      1   LAKELAND
  70561                          7        11     R     1     2      1        1      1   LAKELAND
  70562   0.0106                 7        15     R     1     2                      1   LAKELAND
  70563   0.0313                 7        16     R     1     2                      1   LAKELAND
  70564                          7         7     R     1     2      1        1      1   LAKELAND
  70565                          7         8     R     1     2      1        1      1   LAKELAND
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AIR PUMP AND TRACK ETCH AVERAGES AND ALL LOCATION DATA

LOCATION	AP_MEAN	TE_MEAN	GF_GAMMA	CUT_GAMA	USE	CLASS	TYPE	LEVELS	MATRIAL	A_C	CITYNAME
70566			7	8	R	1	2	1	1	1	LAKELAND
70567				7	R	1	2	1	1	1	LAKELAND
70568			7	8	R	1	2	1	1	1	LAKELAND
70569			7		R	1	2	1	1	1	LAKELAND
70570	0.0086		7	7	R	1	2			1	LAKELAND
70571			6	7	R	1	2	1	1	1	LAKELAND
70572			6	8	R	1	2	1	1	1	LAKELAND
70573	0.0086		6	6	R	1	2			1	LAKELAND
70574			6	6	R	1	2	1	1	1	LAKELAND
70575	0.0042		6	7	R	1	2			1	LAKELAND
70576			6	7	R	1	2	1	1	1	LAKELAND
70577			6	8	R	1	2	1	1	1	LAKELAND
70578			7	9	R	1	2	1	1	1	LAKELAND
70579	0.0064		6	6	R	1	2			1	LAKELAND
70580	0.0089		7	6	R	1	2			1	LAKELAND
70581			6	7	R	1	2	1	1	1	LAKELAND
70582			7	7	R	1	2	1	1	1	LAKELAND
70583			6	6	R	1	2	2	1	1	LAKELAND
70584	0.0168		6	7	R	1	2			1	LAKELAND
70585			6	8	R	1	2	1	1	1	LAKELAND
70586	0.0177		7	11	R	1	2			1	LAKELAND
70587	0.0108		6	7	R	1	2			1	LAKELAND
70588			6	8	R	1	2	1	1	1	LAKELAND
70589			7	9	R	1	2	1	1	1	LAKELAND
70590			8	8	R	1	2	1	1	1	LAKELAND
70591			6	9	R	1	2	1	1	1	LAKELAND
70592			7	8	R	3	2	2	1	1	LAKELAND
70593			7	8	R	3	2	1	1	1	LAKELAND
70594			7	8	R	2	2	1	1	1	LAKELAND
70595			6	8	R	2	2	2	1	1	LAKELAND
70596			7	8	R	2	2	2	1	1	LAKELAND
70597			6	6	R	1	2	1	1	1	LAKELAND
70598			6	6	R	1	2	1	1	1	LAKELAND
70599			7	8	R	3	2	1	1	1	LAKELAND

AIR PUMP AND TRACK ETCH AVERAGES AND ALL LOCATIUN DATA

LOCATION	AP_MEAN	TE_MEAN	GF_GAMMA	CUT_GAMA	USE	CLASS	TYPE	LEVELS	MATRIAL	A_C	CITYNAME
70600			7	10	R	1	2	1	1	1	LAKELAND
70601			7	10	R	3	2	1	1	1	LAKELAND
70602			5	7	R	1	2	1	1	1	LAKELAND
70603			5	5	R	1	2	1	1	1	LAKELAND
70604	0.0066		5	6	R	1	2			1	LAKELAND
70605			6	6	R	1	2	1	1	1	LAKELAND
70606			6	6	R	1	2	1	1	1	LAKELAND
70607			8	9	R	1	2	1	1	1	LAKELAND
70608			7	10	R	1	2	1	1	1	LAKELAND
70609	0.0091		7	11	R	1	2			1	LAKELAND
70610			7	11	R	1	2	1	1	1	LAKELAND
70611			7	13	R	1	2	1	1	1	LAKELAND
70612			8	9	R	1	2	1	1	1	LAKELAND
70613	0.0056		7	12	R	1	2			1	LAKELAND
70614			6	6	R	1	2	1	1	1	LAKELAND
70615	0.0034		7	12	R	1	2			1	LAKELAND
70616			7	10	R	1	2	1	1	1	LAKELAND
70617			8	10	R	1	2	1	1	1	LAKELAND
70618			7	10	R	1	2	1	1	1	LAKELAND
70619			8	10	R	1	2	1	1	1	LAKELAND
70620			7	8	R	1	2	1	1	1	LAKELAND
70621			6	8	R	1	2	1	1	1	LAKELAND
70622			6	9	R	1	2	1	1	1	LAKELAND
70623			8	12	R	1	2	1	1	1	LAKELAND
70624			10	11	R	1	2	1	1	1	LAKELAND
70625			9	12	R	1	2	1	1	1	LAKELAND
70626			8	9	R	1	2	1	1	1	LAKELAND
70627			8	9	R	1	2	1	1	1	LAKELAND
70628	0.0096		8	9	R	1	2			1	LAKELAND
70629	0.0041		8	11	R	1	2			1	LAKELAND
70630			7	9	R	1	2	1	1	1	LAKELAND
70631			7	9	R	1	2	1	1	1	LAKELAND
70632	0.0138		6	10	R	1	2			1	LAKELAND
70633			7	10	R	1	2	1	1	1	LAKELAND

AIR PUMP AND TRACK ETCH AVERAGES ANC ALL LOCATION DATA

LOCATION	AP_MEAN	TE_MEAN	GF_GAMMA	CUT_GAMA	USE	CLASS	TYPE	LEVELS	MATRIAL	A_C	CITYNAME
70634			8	11	R	1	2	1	1	1	LAKELAND
70635			7	9	R	1	2	1	1	1	LAKELAND
70636	0.0050		7	10	R	1	2			1	LAKELAND
70637	0.0044		6	10	R	1	2			1	LAKELAND
70638			7	11	R	1	2	1	1	1	LAKELAND
70639			9	8	R	1	2	1	1	1	LAKELAND
70640			8	10	R	1	2	1	1	1	LAKELAND
70641			7	9	R	1	2	1	1	1	LAKELAND
70642			6	6	R	1	2	1	1	1	LAKELAND
70643			8	9	R	1	2	1	1	1	LAKELAND
70644			9	18	R	1	2	1	1	1	LAKELAND
70645			8	11	R	1	2	1	1	1	LAKELAND
70646			8	10	R	1	2	1	1	1	LAKELAND
70647			7	12	R	1	2	1	1	1	LAKELAND
70648			7	10	R	1	2	1	1	1	LAKELAND
70649			8	13	R	1	2	1	1	1	LAKELAND
70650			7	10	R	1	2	1	1	1	LAKELAND
70651	0.0058		7	11	R	1	2			1	LAKELAND
70652			8	12	R	1	2	1	1	1	LAKELAND
70653	0.0040		6	7	R	1	2			2	LAKELAND
70654			6	8	R	1	2	1	1	1	LAKELAND
70655			10	9	R	1	2	1	1	1	LAKELAND
70656			10	10	R	1	2	1	1	1	LAKELAND
70657			6	6	R	1	2	1	1	1	LAKELAND
70658			8	7	R	1	2	1	1	1	LAKELAND
70659			6	7	R	1	2	1	1	1	LAKELAND
70660			7	8	R	1	2	1	1	1	LAKELAND
70661			7	7	R	1	2	1	1	1	LAKELAND
70662			10	11	R	1	2	1	1	1	LAKELAND
70663			7	8	R	1	2	1	1	1	LAKELAND
70664			7	8	R	1	2	1	1	1	LAKELAND
70665			7	7	R	1	2	1	1	1	LAKELAND
70666	0.0048		6	5	R	1	2			1	LAKELAND
70667			7	8	R	1	2	1	1	1	LAKELAND

AIR PUMP AND TRACK ETCH AVERAGES AND ALL LOCATION DATA

LOCATION	AP_MEAN	TE_MEAN	GF_GAMMA	CUT_GAMA	USE	CLASS	TYPE	LEVELS	MATRIAL	A_C	CITYNAME
70668			7	7	R	1	2	1	1	1	LAKELAND
70669			7	8	R	1	2	1	1	1	LAKELAND
70670			8	10	R	1	2	1	1	1	LAKELAND
70671			8	7	R	1	2	1	1	1	LAKELAND
70672			7	7	R	1	2	1	1	1	LAKELAND
70673			6	7	R	1	2	1	1	1	LAKELAND
70674			6	7	R	1	2	1	1	2	LAKELAND
70675			6	6	R	1	2	1	1	1	LAKELAND
70676	0.0046		10	9	R	1	2			1	LAKELAND
70677	0.0052		6	8	R	1	2			2	LAKELAND
70678			7	9	R	1	2	1	1	1	LAKELAND
70679			6	7	R	1	2	1	1	1	LAKELAND
70680	0.0039		7	6	R	1	2			1	LAKELAND
70681			6	6	R	1	2	1	1	1	LAKELAND
70682	0.0068		7	12	R	1	2			1	LAKELAND
70683	0.0053		7	9	R	1	2			1	LAKELAND
70684			7	9	R	1	1	1	1	1	LAKELAND
70685			7	8	R	1	2	1	1	1	LAKELAND
70686			7	10	R	1	1	1	1	2	LAKELAND
70687	0.0075		7	8	R	1	1			1	LAKELAND
70688	0.0025		8	9	R	1	4			2	LAKELAND
70689			8	9	R	1	4	1	2	2	LAKELAND
70690			8	9	R	1	4	1	2	1	LAKELAND
70691			8	9	R	1	4	1	2	1	LAKELAND
70692			8	8	R	1	4	1	2	1	LAKELAND
70693			10	11	R	1	4	1	2	1	LAKELAND
70694			7	10	R	1	2	1	1	1	LAKELAND
70695			8	12	R	1	2	1	1	1	LAKELAND
70696	0.0055		7	10	R	1	4			2	LAKELAND
70697			7	8	R	1	4	1	2	1	LAKELAND
70698			7	8	R	1	4	1	2	1	LAKELAND
70699			6	7	R	1	4	1	2	1	LAKELAND
70700			7	7	R	1	4	1	2	1	LAKELAND
70701			7	8	R	1	4	1	2	1	LAKELAND

AIR PUMP AND TRACK ETCH AVERAGES AND ALL LOCATION DATA

LOCATION	AP_MEAN	TE_MEAN	GF_GAMMA	OUT_GAMA	USE	CLASS	TYPE	LEVELS	MATRIAL	A_C	CITYNAME
70702			8	9	R	1	4	1	2	1	LAKELAND
70703			8	9	R	1	4	1	2	1	LAKELAND
70704			6	6	R	1	4	1	4	1	LAKELAND
70705			8	7	R	1	4	1	2	1	LAKELAND
70706			6	6	R	1	4	1	2	1	LAKELAND
70707			8	8	R	1	2	1	1	1	LAKELAND
70708	0.0131		8	8	R	1	2			1	LAKELAND
70709			9	11	R	1	2	1	1	1	LAKELAND
70710			10	13	R	1	2	1	1	1	LAKELAND
70711			6	6	R	1	4	1	2	1	LAKELAND
70712			7	8	R	1	4	1	1	2	LAKELAND
70713			12	15	R	1	4	1	2	1	LAKELAND
70714			15	20	R	1	4	1	2	1	LAKELAND
70715			17	21	R	1	4	1	2	1	LAKELAND
70716			8	13	R	1	4	1	2	1	LAKELAND
70717			13	15	R	1	4	1	2	2	LAKELAND
70718	0.0079		7	8	R	1	2			1	LAKELAND
70719			10	10	R	1	2	1	1	1	LAKELAND
70720			9	7	R	1	2	1	1	1	LAKELAND
70721			7	7	R	1	2	1	1	1	LAKELAND
70722			8	7	R	1	2	1	1	1	LAKELAND
70723			12	12	R	1	4	1	2	1	LAKELAND
70724			10	11	R	1	4	1	2	1	LAKELAND
70725			8	9	R	1	4	1	2	1	LAKELAND
70726			8	10	R	1	4	1	2	2	LAKELAND
70727			13	16	R	1	4	1	2	1	LAKELAND
70728			6	8	R	1	2	1	1	1	EATON PARK
70729			6	7	R	1	4	1	1	1	EATON PARK
70730			8	7	R	1	2	1	1	1	EATON PARK
70731			7	9	R	1	2	1	1	1	LAKELAND
70732			12	13	R	1	4	1	2	1	LAKELAND
70733			9	6	R	1	2	1	1	1	EATON PARK
70734			6	7	R	1	2	1	1	2	EATON PARK
70735	0.0084		6	10	R	1	2			1	EATON PARK

AIR PUMP AND TRACK ETCH AVERAGES AND ALL LOCATION DATA

LCCATION	AP_MEAN	TE_MEAN	GF_GAMMA	OUT_GAMA	USE	CLASS	TYPE	LEVELS	MATRIAL	A_C	CITYNAME
70736			6	7	R	1	2	1	1	1	EATON PARK
70737			7	7	R	1	2	1	1	1	EATON PARK
70738			6	7	R	1	2	1	1	1	EATON PARK
70739	0.0072		13	25	R	1	2			1	LAKELAND
70740	0.0255		9	16	R	1	2			1	LAKELAND
70741			6	8	R	1	2	1	1	1	EATON PARK
70742			7	13	R	1	2	1	1	1	LAKELAND
70743			12	20	R	1	2	1	1	1	LAKELAND
70744			7	14	R	1	2	1	1	1	LAKELAND
70745			8	14	R	1	2	1	1	1	LAKELAND
70746	0.0047		7	14	R	1	2			1	LAKELAND
70747			8	7	R	1	2	1	1	2	EATON PARK
70748			21	23	R	1	4	1	2	2	LAKELAND
70749			6	9	R	1	2	1	1	1	EATON PARK
70750			6	7	R	1	2	1	1	1	LAKELAND
70751	0.0395		7	9	R	1	2			1	LAKELAND
70752			10	12	R	1	3	1	1	1	LAKELAND
70753			6	6	U	1	2	1	1	1	LAKELAND
70754			5	6	U	1	2	1	1	1	LAKELAND
70755			6	6	U	1	2	1	1	1	LAKELAND
70756			12	13	R	1	4	1	2	1	LAKELAND
70757			7	10	R	1	2	1	1	1	LAKELAND
70758			6	10	R	1	2	1	1	1	LAKELAND
70759			7	10	R	1	2	1	1	1	LAKELAND
70760			7	12	R	1	2	1	1	1	LAKELAND
70761			8	11	R	1	4	1	1	1	LAKELAND
70762			8	10	R	1	2	1	1	1	LAKELAND
70763			8	8	R	1	2	1	1	1	LAKELAND
70764			8	11	R	1	2	1	1	1	LAKELAND
70765			8	10	R	1	2	1	1	1	LAKELAND
70766	0.0127		11	20	R	1	2			1	MULBERRY
70767			7	9	R	1	2	1	1	1	MULBERRY
70768			7	10	R	1	2	1	1	1	MULBERRY
70769			7	10	R	1	2	1	1	1	MULBERRY

AIR PUMP AND TRACK ETCH AVERAGES AND ALL LOCATION DATA

LOCATION	AP_MEAN	TE_MEAN	GF_GAMMA	CUT_GAMA	USE	CLASS	TYPE	LEVELS	MATRIAL	A_C	CITYNAME
70770			10	9	R	1	4	1	2	1	LAKELAND
70771			8	8	R	1	4	1	2	1	LAKELAND
70772			7	8	R	1	4	1	2	1	LAKELAND
70773			9	10	R	1	4	1	2	1	LAKELAND
70774			8	10	R	1	4	1	2	1	LAKELAND
70775			5	5	N	1	4	1	2	1	LAKELAND
70776			5	5	R	1	4	1	2	1	LAKELAND
70777			7	7	R	1	4	1	2	1	LAKELAND
70778	0.0071		6	7	R	1	4			2	LAKELAND
70779			10	19	R	1	2	1	1	1	MULBERRY
70780			6	11	R	1	2	1	1	1	MULBERRY
70781	0.0032		7	12	R	1	2			1	MULBERRY
70782			8	10	R	1	3	1	1	1	MULBERRY
70783			11	8	R	1	2	1	1	1	MULBERRY
70784			9	8	R	1	2	1	1	1	MULBERRY
70785			8	10	R	1	2	1	1	2	MULBERRY
70786	0.0094		8	8	R	1	2			2	MULBERRY
70787			7	9	R	1	2	1	1	2	MULBERRY
70788			10	14	R	1	2	1	1	1	MULBERRY
70789			8	12	R	1	2	1	1	2	MULBERRY
70790	0.0326		7	9	R	1	2			2	MULBERRY
70791			7	11	R	1	2	1	1	2	MULBERRY
70792	0.0042		11	14	R	1	2			1	MULBERRY
70793	0.0040		8	9	R	1	2			2	MULBERRY
70794			19	22	R	1	3	2	2	2	MULBERRY
70795			7	11	R	1	2	1	1	1	MULBERRY
70796	0.0096		9	14	R	1	2			1	MULBERRY
70797	0.0139		10	30	R	1	2			1	MULBERRY
70798			7	9	R	1	2	1	1	1	MULBERRY
70799	0.0343		7	17	R	1	2			1	MULBERRY
70800			8	11	R	1	3	1	2	2	MULBERRY
70801			10	14	R	1	2	1	1	2	MULBERRY
70802	0.0110		11	20	R	1	2			1	MULBERRY
70803	0.0072		17	24	R	1	3			1	MULBERRY

AIR PUMP AND TRACK ETCH AVERACES AND ALL LOCATION DATA

LOCATION	AP_MEAN	TE_MEAN	GF_GAMMA	CUT_GAMA	USE	CLASS	TYPE	LEVELS	MATRIAL	A_C	CITYNAME
7C804	C.0057		7	7	R	1	2			1	MULBERRY
7C805			12	14	R	1	4	1	2	1	MULBERRY
7C806	C.0098		9	8	R	1	2			2	MULBERRY
70807			7	7	R	1	2	1	1	2	MULBERRY
7C808			19	34	R	1	2	1	1	1	MULBERRY
7C809			7	11	R	1	2	1	1	1	MULBERRY
7C810			7	8	R	1	3	1	2	1	MULBERRY
7C811			9	10	R	1	4	1	2	1	MULBERRY
70813			14	16	R	1	4	1	2	1	MULBERRY
70814			12	14	R	1	4	1	2	1	MULBERRY
7C815			9	8	R	1	2	1	1	1	LAKELAND
7C816	0.0100		7	10	R	1	2			1	LAKELAND
7C817			6	7	R	1	2	1	1	1	LAKELAND
7C818			6	7	R	1	2	1	1	1	LAKELAND
70819			6	7	R	1	4	1	1	1	LAKELAND
7C820			5	5	R	1	4	1	2	1	LAKELAND
7C821			5	5	R	1	4	1	2	1	LAKELAND
70822			5	5	R	1	4	1	2	1	LAKELAND
7C823	0.0034		13	6	R	1	4			1	MULBERRY
70824			11	13	R	1	4	1	2	1	MULBERRY
7C825	C.0114		9	11	R	1	3			2	MULBERRY
70826	0.0100		23	14	R	1	3			1	MULBERRY
70827	0.0495		9	28	R	1	3			2	MULBERRY
7C828			8	8	R	1	3	1	2	2	MULBERRY
70829			8	10	R	1	3	1	2	2	MULBERRY
70831			11	12	R	1	3	1	2	2	MULBERRY
7C832	0.0034		10	9	R	1	3			2	MULBERRY
70833			16	21	R	1	4	1	2	1	MULBERRY
7C834			11	21	R	1	2	1	1	2	MULBERRY
70835			9	20	R	1	2	1	1	2	MULBERRY
7C836			7	10	R	1	2	1	1	2	MULBERRY
7C837			5	6	R	1	4	1	2	1	LAKELAND
7C838			7	7	R	1	4	1	2	2	LAKELAND
7C839			8	9	R	1	4	1	2	1	LAKELAND

AIR PUMP AND TRACK ETCH AVERAGES AND ALL LOCATION DATA

LOCATION	AP_MEAN	TE_MEAN	GF_GAMMA	CUT_GAMA	USE	CLASS	TYPE	LEVELS	MATRIAL	A_C	CITYNAME
7C840			7	8	R	1	4	1	2	1	LAKELAND
7C841			8	9	R	1	4	1	2	1	LAKELAND
7C842			8	8	R	1	4	1	2	1	LAKELAND
7C843			7	8	R	1	4	1	2	1	LAKELAND
7C844			9	9	R	1	2	1	1	1	MULBERRY
7C845			10	12	R	1	3	1	2	2	MULBERRY
7C846			7	9	R	1	4	1	2	1	FT MEADE
7C847			8	9	R	3	2	1	1	1	LAKELAND
7C848			7	9	R	3	2	1	1	1	LAKELAND
7C850			7	8	R	3	2	1	1	1	LAKELAND
7C851			6	8	R	3	2	1	1	1	LAKELAND
7C852			7	8	R	1	2	1	1	1	LAKELAND
7C853			10	16	R	1	2	1	1	2	FT MEADE
7C854	0.0113		12	15	R	1	4			1	FT MEADE
7C855			8	12	R	1	2	1	1	1	FT MEADE
7C856			8	13	R	1	2	1	1	1	MULBERRY
7C857			7	8	R	1	2	1	1	1	MULBERRY
7C858			7	12	R	1	2	1	1	1	MULBERRY
7C859			8	11	R	1	2	1	1	2	MULBERRY
7C860			7	11	R	1	2	1	1	1	MULBERRY
7C861			8	11	R	1	2	1	1	1	MULBERRY
7C862			9	14	R	1	2	1	1	1	MULBERRY
7C863			8	16	R	1	2	1	1	1	MULBERRY
7C864			7		R	1	2	1	1	1	LAKELAND
7C865			9	15	R	1	2	1	1	1	LAKELAND
7C866			7	11	R	1	2	1	1	1	LAKELAND
7C867			7	8	R	1	2	1	1	1	LAKELAND
7C868			6	6	R	1	2	1	1	1	LAKELAND
7C869			8	9	R	1	2	1	1	1	LAKELAND
7C870			6	7	R	1	2	1	1	1	LAKELAND
7C871			6	6	R	1	2	1	1	2	LAKELAND
7C872			8	10	R	1	2	1	1	1	LAKELAND
7C873	0.0057		7	7	R	1	2			2	LAKELAND
7C874			10	11	R	1	2	1	1	1	LAKELAND

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                      AIR PUMP AND TRACK ETCH AVERAGES AND ALL LOCATION DATA

LOCATION  AP_MEAN  TE_MEAN  GF_GAMMA  CUT_GAMA  USE  CLASS  TYPE  LEVELS  MATRIAL  A_C  CITYNAME

 7C875                            6         7    R     1      2      1        1      1   LAKELAND
 7C876                            8         9    R     1      2      1        1      1   LAKELAND
 7C877    0.0143                 11        15    R     1      2                      1   LAKELAND
 7C878                            7        11    R     1      2      1        1      1   LAKELAND
 7C879                            6         9    R     1      2      1        1      1   LAKELAND
 7C880                            8        10    R     1      2      1        1      1   LAKELAND
 7C881                            8        13    R     1      2      1        1      1   LAKELAND
 7C882    0.0064                  9        17    R     1      2                      1   LAKELAND
 7C883                            6         8    R     1      2      1        1      1   LAKELAND
 7C884                            7        10    R     1      2      1        1      1   LAKELAND
 7C885                           10        11    R     1      2      1        1      1   LAKELAND
 7C886                            7        11    R     1      2      1        1      1   LAKELAND
 7C887                            7         9    R     1      2      1        1      1   LAKELAND
 7C888                            6         7    R     1      2      1        1      1   LAKELAND
 7C889                            7         8    R     1      2      1        1      1   LAKELAND
 7C890                            6         7    R     1      2      1        1      1   LAKELAND
 7C891                            5         6    R     1      2      1        1      2   LAKELAND
 70892    0.0075                  8        11    R     1      2                      2   LAKELAND
 7C893    0.0051                 12        18    R     1      4                      1   MULBERRY
 7C894                            9        11    R     1      3      1        2      1   MULBERRY
 7C895    0.0054                 23        24    R     1      3                      2   MULBERRY
 7C896                           13        14    R     1      4      1        2      1   MULBERRY
 7C897                           15        19    R     1      4      1        2      1   MULBERRY
 7C898                            8        10    R     1      2      1        1      1   LAKELAND
 7C899                            9        10    R     1      2      1        1      1   LAKELAND
 70900                            9        12    R     1      2      1        1      2   MULBERRY
 70901    0.0341                  8        10    R     1      2                      1   MULBERRY
 7C902                            8        12    R     1      2      1        1      1   MULBERRY
 70903                            7        10    R     1      3      1        2      2   MULBERRY
 70904                            9        10    R     1      3      1        2      2   MULBERRY
 70905                           19        23    R     1      3      1        2      2   MULBERRY
 7C906                           14        17    R     1      4      1        2      1   MULBERRY
 7C907                           19        31    R     1      4      1        2      1   MULBERRY
 70908                           18        27    R     1      4      1        2      1   MULBERRY
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AIR PUMP AND TRACK ETCH AVERAGES AND ALL LOCATION DATA

LOCATION	AP_MEAN	TE_MEAN	GF_GAMMA	CUT_GAMA	USE	CLASS	TYPE	LEVELS	MATRIAL	A_C	CITYNAME
70909			13	15	R	1	4	1	2	1	MULBERRY
70910			11	13	R	1	2	1	1	1	MULBERRY
70911	0.0069		8	11	R	1	3			1	BARTOW
70912	0.0148		7	10	R	3	2			1	BARTOW
70913	0.0373		7	10	R	3	1			1	BARTOW
70914	0.0513		7	9	R	3	2			1	BARTOW
70915	0.0261		7	9	R	3	2			1	BARTOW
70916	0.0305		7	10	R	5	2			1	BARTOW
70917			7	8	R	1	3	2	2	2	BARTOW
70918			10	10	R	1	2	1	1	2	BARTOW
70919			7	10	R	1	2	1	1	1	BARTOW
70920			8	9	R	1	2	1	1	1	FT MEADE
70921			8	10	R	1	2	1	1	1	BARTOW
70922			11	21	R	1	2	1	1	2	FT MEADE
70923			11	18	R	1	2	1	1	2	BARTOW
70924			10	17	R	1	2	1	1	2	FT MEADE
70925			10	19	R	1	2	1	1	2	FT MEADE
70926			10	14	R	1	3	1	2	2	BARTOW
70927			8	10	R	1	2	1	1	2	FT MEADE
70928			11	14	R	1	2	2	1	1	FT MEADE
70929			10	18	R	1	2	1	1	2	FT MEADE
70930			8	0	R	3	2	1	1	1	LAKELAND
70931			9	10	R	3	2	2	1	1	LAKELAND
70932			9	10	R	3	2	1	1	1	LAKELAND
70933			8	10	R	3	2	1	1	1	LAKELAND
70934			7	10	R	3	2	1	1	1	LAKELAND
70935			8	10	R	1	2	1	1	1	LAKELAND
70936			8	10	R	1	2	1	1	1	LAKELAND
70937	0.0075		8	9	R	1	2			1	MULBERRY
70938			7	10	R	1	2	1	1	1	LAKELAND
70939			8	12	R	1	2	1	1	1	LAKELAND
70940			10	15	R	1	2	1	1	1	LAKELAND
70941			7	8	R	1	2	1	1	1	LAKELAND
70942	0.0098		6	8	R	1	2			1	LAKELAND

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                    AIR PUMP AND TRACK ETCH AVERAGES AND ALL LOCATION DATA

LOCATION  AP_MEAN  TE_MEAN  GF_GAMMA  OUT_GAMA  USE  CLASS  TYPE  LEVELS  MATRIAL  A_C  CITYNAME

 70943                           7         8     U     1      4      1        2      2   LAKELAND
 70944                           9        10     U     1      4      1        2      1   LAKELAND
 70945                          20        22     R     1      4      1        2      1   EATON PARK
 70946    0.0084                16        16     R     1      4                      1   EATON PARK
 70947                          21        24     R     1      4      1        2      2   LAKELAND
 70948                          15        17     R     1      4      1        2      1   LAKELAND
 70949                          18        19     R     1      4      1        2      1   LAKELAND
 70950                           9        14     U     1      2      1        1      1   LAKELAND
 70951                           6         9     R     1      2      1        1      2   EATON PARK
 70952    0.0351                22        20     R     1      4                      1   EATON PARK
 70953                          11        15     R     1      2      1        1      1   LAKELAND
 70954                           9        13     R     1      2      1        1      2   MULBERRY
 70955                          12        15     R     1      3      1        2      1   MULBERRY
 70956                           8        10     U     1      2      1        1      1   LAKELAND
 70957                          11        14     U     1      4      1        2      2   MULBERRY
 70958    0.0179                10        17     U     1      2                      1   LAKELAND
 70959                           7         7     U     1      2      1        1      1   LAKELAND
 70960                           6         6     U     1      2      1        1      1   LAKELAND
 70961                           7         6     N     1      2      1        1      1   LAKELAND
 70962                           6         6     N     1      2      1        1      1   LAKELAND
 70963                           7         6     N     1      2      1        1      1   LAKELAND
 70964                           7         7     N     1      2      1        1      1   LAKELAND
 70965                           6         6     N     1      2      1        1      1   LAKELAND
 70966                           6         6     N     1      2      1        1      1   MULBERRY
 70967                           6         6     N     1      2      1        1      1   LAKELAND
 70968                           6         6     N     1      2      1        1      1   MULBERRY
 70969                           6         6     N     1      2      1        1      1   MULBERRY
 70970                           8         8     N     1      2      1        1      1   MULBERRY
 70971                           6         6     N     1      2      1        1      1   LAKELAND
 70972                           6         6     N     1      2      1        1      1   LAKELAND
 70973                           5         5     N     1      2      1        1      1   LAKELAND
 70974                           6         5     N     1      2      1        1      1   LAKELAND
 70975                           5         5     N     1      2      1        1      2   LAKELAND
 70976                           5         5     N     1      2      1        1      1   LAKELAND
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                     AIR PUMP AND TRACK ETCH AVERAGES AND ALL LOCATION DATA                         23

LOCATION  AP_MEAN  TE_MEAN  GF_GAMMA  OUT_GAMA  USE  CLASS  TYPE  LEVELS  MATRIAL  A_C  CITYNAME

  70977                         6         5      N     1      2      1        1      1   LAKELAND
  70978                         5         5      N     1      2      1        1      1   LAKELAND
  70979                         7        11      U     1      2      1        1      1   BARTOW
  70980                         7         9      U     1      2      1        1      1   BARTOW
  70981                         7         7      U     1      2      1        1      1   BARTOW
  70982                         5         6      U     1      4      1        2      1   PIERCE
  70983                        12         9      U     1      2      1        1      2   BARTOW
  70984                        11        10      U     1      2      1        1      1   BARTOW
  70985                        10        10      U     1      2      1        1      1   BARTOW
  70986   0.0029                6         6      N     1      2                      1   DAVENPORT
  70987                         5         5      N     1      3      1        2      2   DAVENPORT
  70988                         5         5      N     1      2      1        1      2   DAVENPORT
  70989                         5         5      N     1      2      1        1      2   DAVENPORT
  70990                         5         6      N     1      2      1        1      1   DAVENPORT
  70991                         5         5      N     1      2      1        1      1   DAVENPORT
  70992                         7         7      N     1      2      1        1      1   DAVENPORT
  70993                         5         5      N     1      2      1        1      1   DAVENPORT
  70994                         5         5      N     1      2      1        1      2   DAVENPORT
  70995                         8         6      N     1      2      1        1      1   DAVENPORT
  70996                         5         5      N     1      2      1        2      2   DAVENPORT
  70997                         5         6      N     1      3      1        2      1   DAVENPORT
  70998                         7         7      N     1      2      1        1      2   DAVENPORT
  70999                         5         5      N     1      2      1        1      2   DAVENPORT
  71000                         5         5      N     1      3      1        2      2   DAVENPORT
  71001                         6         6      N     1      2      1        1      1   LAKELAND
  71002                         6         6      N     1      2      1        1      1   MULBERRY
  71003                         6         7      N     1      2      1        1      1   MULBERRY
  71004                         6         6      N     1      2      1        1      1   MULBERRY
  71005                         6         6      N     1      2      1        1      1   MULBERRY
  71006                         6         6      N     1      2      1        1      1   MULBERRY
  71007                         6         6      N     1      2      1        1      1   MULBERRY
  71008                         6         6      N     1      2      1        1      1   POLK CITY
  71009                         6         6      N     1      2      1        1      1   POLK CITY
  71010                         5         6      N     1      3      1        1      1   POLK CITY
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AIR PUMP AND TRACK ETCH AVERAGES ANC ALL LOCATION DATA

LOCATION	AP_MEAN	TE_MEAN	GF_GAMMA	OUT_GAMA	USE	CLASS	TYPE	LEVELS	MATRIAL	A_C	CITYNAME
71011			7	8	N	1	2	1	1	1	POLK CITY
71012			6	7	N	1	2	1	1	1	POLK CITY
71013	0.0038		6	6	N	1	2			1	POLK CITY
71014			5	6	N	1	2	1	1	1	POLK CITY
71015			5	6	N	1	2	1	1	2	POLK CITY
71016			6	6	N	1	2	1	1	1	POLK CITY
71017			6	7	N	2	2	1	1	1	POLK CITY
71018			7	8	N	2	1	1	1	1	POLK CITY
71019	0.0024		7	7	N	1	2			2	POLK CITY
71020			6	6	N	1	2	1	1	1	POLK CITY
71021			6	6	N	1	2	1	1	2	DAVENPORT
71022			5	5	N	1	2	1	1	2	DAVENPORT
71023	0.0041		5	5	N	1	2			2	DAVENPORT
71024			5	5	N	1	2	1	1	2	DAVENPORT
71025			6	6	N	1	2	1	1	1	DAVENPORT
71026			6	6	N	1	2	1	1	1	DAVENPORT
71027			5	6	N	1	2	1	1	1	DAVENPORT
71028			5	5	N	1	2	1	1	2	DAVENPORT
71029			5	5	N	1	3	1	2	2	DAVENPORT
71030			5	5	N	1	2	1	1	1	DAVENPORT
71031			5	5	N	1	2	1	1	1	HAINES CITY
71032			5	5	N	1	2	1	1	2	HAINES CITY
71033			6	6	N	1	2	1	1	1	HAINES CITY
71034	0.0025		6	6	N	1	2			2	HAINES CITY
71035	0.0011		6	6	N	1	2			2	HAINES CITY
71036	0.0045		6	5	N	1	2			2	HAINES CITY
71037			5	6	N	1	2	1	1	2	HAINES CITY
71038			5	5	N	1	2	1	1	1	HAINES CITY
71039			5	5	N	3	2	1	1	1	HAINES CITY
71040			5	5	N	3	2	1	1	1	HAINES CITY
71041			5	5	N	3	2	1	1	1	HAINES CITY
71042			5	5	N	1	2	1	1	1	HAINES CITY
71043			5	5	N	3	2	1	1	1	HAINES CITY
71044			5	5	N	1	3	1	1	1	HAINES CITY

AIR PUMP AND TRACK ETCH AVERAGES AND ALL LOCATION DATA

LOCATION	AP_MEAN	TE_MEAN	GF_GAMMA	OUT_GAMA	USE	CLASS	TYPE	LEVELS	MATRIAL	A_C	CITYNAME
71045			5	5	N	3	2	1	1	1	HAINES CITY
71046			5	5	N	3	2	1	1	1	HAINES CITY
71047	0.0028		5	5	N	1	3			1	HAINES CITY
71048			5	5	N	1	2	1	1	1	HAINES CITY
71049			5	5	N	1	2	1	1	1	HAINES CITY
71050			5	5	N	1	3	1	2	1	HAINES CITY
71051			7	6	N	1	2	1	1	2	HAINES CITY
71052			5	5	N	1	2	1	1	1	HAINES CITY
71053			5	6	N	1	2	1	1	1	HAINES CITY
71054	0.0025		6	6	N	1	2			2	HAINES CITY
71055			5	5	N	1	2	1	1	1	HAINES CITY
71056			5	6	N	1	2	1	1	1	HAINES CITY
71057			5	6	N	1	2	1	1	2	HAINES CITY
71058	0.0030		6	7	N	1	2			1	HAINES CITY
71059	0.0033		6	6	N	1	2			1	HAINES CITY
71060			5	5	N	1	2	1	1	1	HAINES CITY
71061			6	6	N	1	3	1	2	1	HAINES CITY
71062			5	5	N	1	2	1	1	1	HAINES CITY
71063	0.0022		5	5	N	1	3			2	HAINES CITY
71064	0.0118		5	5	N	1	2			1	HAINES CITY
71065			5	5	N	1	2	1	1	1	HAINES CITY
71066	0.0027		5	5	N	1	2			1	HAINES CITY
71067			5	5	N	1	2	1	1	2	FROSTPROOF
71068			5	5	N	1	2	1	1	1	FROSTPROOF
71069			5	5	N	1	2	1	1	2	FROSTPROOF
71070			6	5	N	1	2	1	1	1	FROSTPROOF
71071			8	10	N	1	2	1	1	2	FROSTPROOF
71072			5	6	N	1	2	1	1	1	FROSTPROOF
71073			5	5	N	1	2	1	1	1	FROSTPROOF
71074			5	5	N	1	2	1	1	1	FROSTPROOF
71075			5	5	N	1	2	1	1	1	FROSTPROOF
71076			5	6	N	1	2	1	1	2	FROSTPROOF
71077			5	5	N	1	3	1	2	1	FROSTPROOF
71078			5	5	N	1	2	1	1	2	FROSTPROOF

AIR PUMP AND TRACK ETCH AVERAGES AND ALL LOCATION DATA

LCCATION	AP_MEAN	TE_MEAN	GF_GAMMA	OLT_GAMA	USE	CLASS	TYPE	LEVELS	MATRIAL	A_C	CITYNAME
71C79			5	5	N	1	2	1	1	1	FRUSTPROOF
71C80			5	5	N	1	2	1	1	1	PCLK CITY
71C81			6	5	N	1	2	1	1	1	POLK CITY
71082			6	6	N	1	2	2	1	1	PCLK CITY
71C83			7	8	N	1	2	1	1	1	PCLK CITY
71C84			5	5	N	1	3	1	1	1	POLK CITY
71C85			6	6	N	1	2	1	1	1	POLK CITY
71C86			6	6	N	1	2	1	1	2	PCLK CITY
71C87			7		N	1	3	1	1	2	POLK CITY
71C88			5		N	1	4	1	2	2	PCLK CITY
71C89			5	6	N	1	4	1	2	2	POLK CITY
71090			5	5	N	1	2	1	1	1	PCLK CITY
71091			5	5	N	1	4	1	2	2	PCLK CITY
71092			5	6	N	1	2	1	1	1	DUNDEE
71C93			5	6	N	1	2	1	1	1	DUNDEF
71C94			5	5	N	1	2	1	1	2	DUNDEE
71C95			5	5	N	1	2	1	1	1	DUNDEE
71C96	C.0041		6	6	N	1	2			1	DUNDEE
71C97			6	6	N	1	2	1	1	1	DUNDEE
71098			5	5	N	1	2	1	1	1	DUNDEE
71C99			5	5	N	1	2	1	1	2	DUNDEE
71100			5	6	N	1	2	1	1	2	DUNDEE
71101			6	7	N	1	1	1	1	2	DUNDEE
711C2			7	6	N	1	3	1	2	2	DUNDEE
71103			6	6	N	1	2	1	1	1	DUNDEE
71104			5	6	N	1	3	1	2	2	DUNDEE
71105			5	6	N	1	2	1	1	1	DUNDEE
71106			5	6	N	1	2	1	1	2	CUNDEE
71107			5	5	N	1	3	1	2	2	DUNDEE
71108			5	6	N	1	2	1	1	1	DUNDEE
711C9			5	5	N	1	3	1	1	1	DUNDEE
71110			10	12	N	1	2	1	1	1	CUNDEE
71111			5	5	N	1	3	1	2	1	DUNDEE
71112			5	6	N	1	2	1	1	1	DUNDEE

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               AIR PUMP AND TRACK ETCH AVERAGES AND ALL LOCATION DATA
LOCATION  AP_MEAN  TE_MEAN  GF_GAMMA  OUT_GAMA  USE  CLA_S  TYPE  LEVELS  MATRIAL  A_C  CITYNAME

 71113    0.0024               9         5       N     1      2                     2   DUNDEE
 71114                         5         5       N     1      3      1        1     2   DUNDEE
 71115                         6         5       N     3      2      1        1     1   LAKE WALES
 71116    0.0081               5         5       N     3      2                     1   LAKE WALES
 71117                         6         6       N     3      2      1        1     1   LAKE WALES
 71118                         6         6       N     3      2      1        1     1   LAKE WALES
 71119                         5         5       N     3      2      1        1     1   LAKE WALES
 71120                         5         5       N     3      2      1        1     1   LAKE WALES
 71121                         5         5       N     3      2      1        1     1   LAKE WALES
 71122                         5         5       N     3      2      1        1     1   LAKE WALES
 71123                         5         6       N     3      2      1        1     1   LAKE WALES
 71124                         6         5       N     3      2      1        1     1   LAKE WALES
 71125                         8         6       N     5      2      1        1     1   LAKE WALES
 71126                         6         5       N     3      2      1        1     1   LAKE WALES
 71127                         5         6       N     1      3      1        2     2   LAKE WALES
 71128                         5         5       N     1      3      1        2     2   LAKE WALES
 71129                         5         5       N     1      3      1        2     2   LAKE WALES
 71130                         5         5       N     1      3      1        2     2   LAKE WALES
 71131                         6         6       N     1      4      1        2     1   LAKE WALES
 71132                         5         5       N     1      2      1        1     1   LAKE WALES
 71133                         5         5       N     1      2      1        1     1   LAKE WALES
 71134                         5         5       N     1      2      1        1     1   LAKE WALES
 71135                         5         5       N     1      2      2        1     1   LAKE WALES
 71136                         5         5       N     1      2      1        1     1   LAKE WALES
 71137                         9         7       N     1      2      1        1     1   LAKE WALES
 71138                         5         5       N     1      2      1        1     1   LAKE WALES
 71139    0.0035               6         5       N     1      2                     1   LAKE WALES
 71140                         6         5       N     1      2      1        1     1   LAKE WALES
 71141                         5         6       N     1      2      1        1     1   LAKE WALES
 71142                         5         6       N     1      2      1        1     2   LAKE WALES
 71143    0.0033               5         5       N     1      2                     1   LAKE WALES
 71144                         6         5       N     1      2      1        1     1   LAKE WALES
 71145                         5         5       N     1      2      1        1     2   LAKE WALES
 71146                         5         5       N     1      2      1        1     2   LAKE WALES
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AIR PUMP AND TRACK ETCH AVERAGES AND ALL LOCATION DATA

LOCATION	AP_MEAN	TE_MEAN	GF_GAMMA	OUT_GAMA	USE	CLASS	TYPE	LEVELS	MATRIAL	A_C	CITYNAME
71147			5	5	N	1	2	1	1	1	LAKE WALES
71148			5	5	N	1	2	1	1	1	LAKE WALES
71149			6	6	N	1	2	1	1	1	BARTOW
71150			6	6	N	1	2	1	1	1	BARTOW
71151			6	6	N	1	2	1	1	1	BARTOW
71152			5	5	N	1	2	1	1	1	BARTOW
71153			5	5	N	1	2	1	1	1	BARTOW
71154			5	5	N	1	2	1	1	1	BARTOW
71155			5	5	N	1	2	1	1	1	BARTOW
71156			5	5	N	1	2	1	1	2	BARTOW
71157			5	5	N	1	2	1	1	2	BARTOW
71158			5	5	N	1	2	1	1	2	BARTOW
71159			5	5	N	1	2	1	1	1	BARTOW
71160			5	6	N	1	2	1	1	2	BARTOW
71161			5	5	N	1	2	1	1	2	BARTOW
71162			5	5	N	1	2	1	1	2	BARTOW
71163			5	5	N	1	2	1	1	1	BARTOW
71164			5	5	N	1	2	1	1	2	WINTER HAVEN
71165			5	5	N	1	2	1	1	2	WINTER HAVEN
71166			5	5	N	1	2	1	1	1	WINTER HAVEN
71167			7	6	N	1	1	1	2	1	WINTER HAVEN
71168	0.0018		5	5	N	1	2			1	WINTER HAVEN
71169			5	5	N	1	2	1	1	2	WINTER HAVEN
71170			6	7	N	1	2	1	1	2	WINTER HAVEN
71171			5	5	N	1	2	1	1	2	FROSTPROOF
71172			5	5	N	1	2	1	2	2	FROSTPROOF
71173			10	11	N	1	2	1	1	2	FROSTPROOF
71174			10	10	N	1	2	1	1	1	FROSTPROOF
71175			10	13	N	1	2	1	1	1	FROSTPROOF
71176			9	10	N	1	2	1	1	2	FROSTPROOF
71177			7	9	N	1	2	1	1	1	BARTOW
71178			5	5	N	1	2	1	1	2	FROSTPROOF
71179			9	10	N	1	2	1	1	2	FROSTPROOF
71180			10	11	N	1	2	1	1	1	FROSTPROOF

AIR PUMP AND TRACK ETCH AVERAGES AND ALL LOCATION DATA

LOCATION	AP_MEAN	TE_MEAN	GF_GAMMA	OUT_GAMA	USE	CLASS	TYPE	LEVELS	MATRIAL	A_C	CITYNAME
71181			5	5	N	1	2	1	1	1	FROSTPROOF
71182			5	5	N	1	2	1	1	1	FROSTPROOF
71183			5	5	N	1	2	1	1	2	FROSTPROOF
71184			9	9	N	1	2	1	1	1	FROSTPROOF
71185			10	11	N	1	2	1	1	1	FROSTPROOF
71186			10	11	N	1	2	1	1	2	FROSTPROOF
71187			11	11	N	1	2	1	1	2	FROSTPROOF
71188			11	12	N	1	2	1	1	2	FROSTPROOF
71189			8	9	M	1	2	1	1	1	LAKELAND
71191			7	9	M	1	2	1	1	1	LAKELAND
71192			8	9	M	1	2	1	1	1	LAKELAND
71193			10	10	M	1	2	1	1	2	LAKELAND
71194			10	10	M	1	2	1	1	1	LAKELAND
71195			9	10	M	1	2	1	1	1	LAKELAND
71196	0.0224		9	8	M	1	2			1	LAKELAND
71197			7	7	M	1	2	1	1	1	LAKELAND
71198			7	8	M	1	2	1	1	1	LAKELAND
71199			7	7	M	1	2	1	1	1	LAKELAND
71200			6	6	M	1	2	1	1	1	LAKELAND
71201			7	7	M	1	2	1	1	1	LAKELAND
71202			6	7	M	1	2	1	1	1	LAKELAND
71203			7	7	M	1	2	1	1	1	LAKELAND
71204			6	7	M	1	2	1	1	1	LAKELAND
71205			6	7	M	1	2	1	1	1	LAKELAND
71206	0.0204		6	6	M	1	2			1	LAKELAND
71207			6	6	N	3	2	1	1	1	LAKELAND
71208			6	6	M	1	2	1	1	1	LAKELAND
71209			6	6	M	1	2	1	1	1	LAKELAND
71210			6	6	M	1	2	1	1	1	LAKELAND
71211			6	7	M	1	2	1	1	1	LAKELAND
71212			6	6	M	1	2	1	1	1	LAKELAND
71213			9	8	M	1	1	1	1	1	LAKELAND
71214			8	8	M	1	2	1	1	1	LAKELAND
71215			6	6	M	1	2	1	1	1	LAKELAND

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                    AIR PUMP AND TRACK ETCH AVERAGES AND ALL LOCATION DATA                    30
LOCATION  AP_MEAN  TE_MEAN  GF_GAMMA  OUT_GAMA  USE  CLASS  TYPE  LEVELS  MATRIAL  A_C  CITYNAME

 71216                         6         7       M     1     2      1        1      1   LAKELAND
 71217                         6         6       M     1     2      1        1      1   LAKELAND
 71218                         8         7       M     1     2      1        1      1   LAKELAND
 71219                         8         6       M     1     2      1        1      1   LAKELAND
 71220                        11         6       M     1     2      1        1      1   LAKELAND
 71221                         6         7       M     1     2      1        1      1   LAKELAND
 71222                         6         7       M     1     2      1        1      1   LAKELAND
 71223                         7         8       M     1     2      1        1      3   LAKELAND
 71224                         7         7       M     1     2      1        1      1   LAKELAND
 71225                         7         8       M     1     2      1        1      1   LAKELAND
 71226                         8         7       M     1     2      2        1      1   LAKELAND
 71227                         6         6       N     3     2      1        1      1   LAKELAND
 71228                         7         8       M     1     2      1        1      1   LAKELAND
 71229                         6         6       M     1     2      1        1      1   LAKELAND
 71230                         6         5       M     1     2      1        1      1   LAKELAND
 71231                         7         8       M     1     2      1        1      1   LAKELAND
 71232                         7         7       M     1     2      1        1      1   LAKELAND
 71233                         9         8       M     1     2      1        1      1   LAKELAND
 71234                         6         6       M     1     2      1        1      1   LAKELAND
 71235                         8         7       M     1     2      1        1      1   LAKELAND
 71236                         6         6       M     1     2      1        1      1   LAKELAND
 71237                         6         6       M     1     2      1        1      1   LAKELAND
 71238                         6         7       M     1     2      1        1      1   LAKELAND
 71239                         6         7       M     1     2      1        1      1   LAKELAND
 71240                         6         6       N     1     2      1        1      2   WINTER HAVEN
 71241                         6         6       N     1     2      1        1      1   WINTER HAVEN
 71242                         8         9       N     1     2      1        1      2   WINTER HAVEN
 71243                         6         6       N     1     2      1        1      2   WINTER HAVEN
 71244                         7         7       N     1     2      1        1      2   WINTER HAVEN
 71245                         7         7       N     1     2      1        1      2   WINTER HAVEN
 71246                         6         7       N     1     2      1        1      2   WINTER HAVEN
 71247                         8         6       N     1     2      1        1      2   WINTER HAVEN
 71248                         6         6       N     1     2      1        1      2   WINTER HAVEN
 71249                         5         5       N     1     2      1        1      2   WINTER HAVEN
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AIR PUMP AND TRACK ETCH AVERAGES AND ALL LOCATION DATA

LOCATION	AP_MEAN	TE_MEAN	GF_GAMMA	OUT_GAMA	USE	CLASS	TYPE	LEVELS	MATRIAL	A_C	CITYNAME
71250			5	5	N	1	2	1	1	1	WINTER HAVEN
71251			5	5	N	1	2	1	1	1	WINTER HAVEN
71252			6	6	N	1	2	1	1	2	WINTER HAVEN
71253			5	5	N	1	2	1	1	2	WINTER HAVEN
71254			5	6	N	1	2	1	1	2	WINTER HAVEN
71255			5	6	N	1	2	1	1	2	WINTER HAVEN
71256			6	7	N	1	2	1	1	1	WINTER HAVEN
71257			5	5	N	1	2	1	1	1	WINTER HAVEN
71258			6	6	N	1	2	1	1	1	WINTER HAVEN
71259			5	5	N	1	2	1	1	2	WINTER HAVEN
71260			7	6	N	1	2	1	1	2	WINTER HAVEN
71261			5	5	N	1	2	1	1	2	BARTOW
71262			5	5	N	1	1	1	1	2	BARTOW
71263			5	5	N	1	2	1	1	2	BARTOW
71264			5	5	N	1	2	1	1	2	BARTOW
71265			5	6	N	1	2	1	1	2	BARTOW
71266	0.0050		6	8	N	1	2			2	BARTOW
71267			5	5	N	1	2	1	1	2	WINTER HAVEN
71268			6	5	N	1	2	1	1	1	WINTER HAVEN
71269			6	5	N	1	2	1	1	1	WINTER HAVEN
71270			5	5	N	1	2	1	1	1	WINTER HAVEN
71271	0.0056		4	5	N	1	2			1	WINTER HAVEN
71272			5	5	N	1	2	1	1	1	WINTER HAVEN
71273			5	5	N	1	2	1	1	1	WINTER HAVEN
71274			5	5	N	1	2	1	1	1	WINTER HAVEN
71275			5	5	N	1	2	1	1	1	WINTER HAVEN
71276			5	5	N	1	2	1	1	1	WINTER HAVEN
71277			5	5	N	1	2	1	1	1	WINTER HAVEN
71278			5	5	N	1	2	1	1	1	WINTER HAVEN
71279			23	5	N	1	2	1	1	1	WINTER HAVEN
71280			5	5	N	1	2	1	1	1	WINTER HAVEN
71281			5	5	N	1	2	1	1	1	WINTER HAVEN
71282			5	5	N	1	2	1	1	1	WINTER HAVEN
71283			5	5	N	1	2	1	1	1	WINTER HAVEN

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                AIR PUMP AND TRACK ETCH AVERAGES AND ALL LOCATION DATA
LOCATION  AP_MEAN  TE_MEAN  GF_GAMMA  OUT_GAMA  USE  CLASS  TYPE  LEVELS  MATRIAL  A_C   CITYNAME

 71285                         5         5      N     1      2      1       1      1   WINTER HAVEN
 71286                         5         5      N     1      2      1       1      1   WINTER HAVEN
 71287                         6         6      M     1      2      1       1      1   LAKELAND
 71288                         9         7      M     1      2      1       1      1   LAKELAND
 71289                         8         8      M     1      2      1       1      1   LAKELAND
 71290                         9         7      M     1      2      1       1      1   LAKELAND
 71291                         7         7      M     1      2      1       1      1   LAKELAND
 71292                         7         6      M     1      2      1       1      1   LAKELAND
 71293                         8         6      M     1      2      1       1      1   LAKELAND
 71294                         6         7      M     1      2      1       1      1   LAKELAND
 71295                         6         6      M     1      2      1       1      1   LAKELAND
 71296                         6         6      M     1      2      2       1      1   LAKELAND
 71297                         7         6      M     1      2      1       1      1   LAKELAND
 71298                         9         8      M     1      2      1       1      1   LAKELAND
 71299                         7         7      M     1      2      1       1      1   LAKELAND
 71300                         8         7      M     1      2      1       1      1   LAKELAND
 71360                         7         8      M     1      2      1       1      1   LAKELAND
 71361                         5         6      M     1      2      1       1      1   LAKELAND
 71362                         6         6      M     1      2      1       1      1   LAKELAND
 71363                         6         6      M     1      2      1       1      1   AUBURNDALE
 71364                         6         6      R     1      2      1       1      1   AUBURNDALE
 71365                         6         6      R     1      2      1       1      1   AUBURNDALE
 71366                         6         6      R     1      2      1       1      1   AUBURNDALE
 71368                         6         6      M     1      2      1       1      1   AUBURNDALE
 71369                         5         5      M     1      2      1       1      1   WINTER HAVEN
 71370                         5         5      M     1      2      1       1      1   WINTER HAVEN
 71371    0.0043               5         5      M     1      2                     1   WINTER HAVEN
 71372                         5         5      M     1      2      1       1      1   WINTER HAVEN
 71373                         5         5      M     1      2      1       1      1   WINTER HAVEN
 71374                         5         5      M     1      2      1       1      1   WINTER HAVEN
 71375                         6         6      M     1      2      1       1      1   AUBURNDALE
 71376                         6         6      M     1      2      1       1      1   AUBURNDALE
 71377    0.0070               6         6      M     1      2                     1   AUBURNDALE
 71378                                          M     1      2      1       1      1   AUBURNDALE
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AIR PUMP AND TRACK ETCH AVERAGES AND ALL LOCATION DATA

LOCATION	AP_MEAN	TE_MEAN	GF_GAMMA	OUT_GAMA	USE	CLASS	TYPE	LEVELS	MATRIAL	A_C	CITYNAME
71379			6	6	M	1	2	1	1	1	AUBURNDALE
71380	0.0029		6	6	M	1	3			2	AUBURNDALE
71381			5	6	M	1	2	1	1	1	WINTER HAVEN
71382			5	6	M	1	2	1	1	1	WINTER HAVEN
71383			5	6	M	1	2	1	1	1	WINTER HAVEN
71384			5	5	M	1	2	1	1	1	WINTER HAVEN
71385			5	5	M	1	2	1	1	1	WINTER HAVEN
71386			5	5	M	1	2	1	1	1	WINTER HAVEN
71387			5	5	M	1	2	1	1	1	WINTER HAVEN
71388			5	5	M	1	2	1	1	1	WINTER HAVEN
71389			5	5	M	1	2	1	1	1	WINTER HAVEN
71390			5	5	M	1	2	1	1	1	WINTER HAVEN
71391			5	5	M	1	2	1	1	1	WINTER HAVEN
71392			5	5	M	1	2	1	1	1	WINTER HAVEN
71393			5	5	M	1	2	1	1	1	WINTER HAVEN
71394			8	10	M	1	3	1	2	2	FT MEADE
71395			14	12	R	1	4	1	2	2	FT MEADE
71356			16	18	R	1	4	1	2	1	FT MEADE
71397	0.0100		7	7	M	1	4			1	FT MEADE

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